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THE

ENGLISH CYCLOPÆDIA.

A New Dictionary of Universal Knowledge.

CONDUCTED BY CHARLES KNIGHT.

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ARTS AND SCIENCES.—VOLUME IV.

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F is a labio-dental aspirate bearing the same relation to the other labio-dental aspirate V which the letters called *tenues*, *p*, *k*, *t*, bear to the *mediæ*, *b*, *g*, *d*. It occupies the sixth place in the English as in the Latin alphabet, thus corresponding with the digamma of the old Greek alphabet, and the vau of the Hebrew. In power and form it is likewise closely related to those two letters. [ALPHABET.]

The letter F is interchangeable with the other aspirates *ch* or *h* and *th*, and also with the lip-letters *p* and *b*.

1. F in Latin corresponds to *h* in Spanish, as Latin *formoso*, beautiful, Spanish *hermoso*; Latin *femina*, female, Spanish *hembra*; Latin *fugere*, fly, Spanish *huir*. Other examples may readily be found in a Spanish Dictionary under the letter *h*. The same change prevailed between the Latin of Rome and the Sabine dialect of that language.

2. F in Latin corresponds to *th* in Greek, as Latin *fera*, a wild beast, Greek *θηρ*. Latin *fle*, weep, Greek *θρε*, as seen in *θρηνος*. Indeed this interchange prevailed among the dialects of the Greek language itself as in **ουφαρ** and **ουθαρ**; **φλαν** and **θλαν**; **φλιβω** and **θλιβω**. This however seems to depend on the proximity of the letters *l* and *r*. (See L.)

3. F in Latin corresponds to *b* in German and English, as *frang-ere*, brech-en, to break; *frater*, bruder, brother; *fago*, buche, beech, &c.

4. F in English and German to *p* in Latin, as *pelli*, fell, fell (comp. fellmonger); *ped*, fuss, foot; *pug-na-re*, fechten, to fight, &c.

FABLE, Fabula in Latin, in its general sense means a fictitious narrative, but it also means more particularly a species of didactic composition, consisting of a short fictitious tale inculcating a moral truth or precept. As such it is divided into two sorts, the parable and the apologue. The former narrates some incident, which, although it may not have happened exactly as the narrator supposes, yet could have happened at any time, there being nothing impossible or improbable in it. Of this description are many of the parables contained in the Scriptures, and especially in the New Testament, it being a favourite mode with our Saviour of illustrating his precepts by similitudes. When, for instance, he spoke of the master who, before setting out on a long journey, intrusted certain talents or sums of money to each of his three servants, he did not mean that such a fact had occurred at any particular time, though it might have occurred, but he chose this figure as presenting the ways of God with regard to the mental or spiritual talents he has gifted men with, and which he expects them to cultivate and render useful in proportion to their capacities. The second species of moral fable, called apologue, relates facts which are evidently untrue, and cannot have happened; such as animals, or even inanimate things, speaking, but which serve as comparisons for the actions of men. Such was the well-known apologue of Menenius Agrippa, addressed to the plebs of Rome, who had revolted against the patricians, in which he told them of the various limbs of the human body having once revolted against the belly. (Livy, ii. 32.) Most of the fables which are called Æsopian are apologues, although some are of the parable kind; for example, that of Æsop and the villain who threw a stone at him. (Phædrus, iii. 5.)

The apologue is one of the oldest forms of composition, being well calculated to strike the minds of men in a rude state. Homer's War of the Mice and the Frogs is a composition of the nature of the apologue; only being extended to a considerable length, and including a succession of incidents, it is classed among the heroico-comic poems, whilst the apologue, or fable properly so called, points out only one particular incident from which it draws a moral. In the same manner, in modern times, the 'Animali Parlanti,' or 'Court and Parliament of Beasts' of Casti must be classed among the mock epic poems, although it may be said to consist of a series of apologues, each pointing to some particular error, or abuse, in the state of society, and in the conduct of men. It is probable that the older and simpler mythological fables of the gods and heroes among the ancients were originally intended by the early patriarchs or priests to illustrate by allegory the attributes of the Creator, the phenomena of nature, and the progress of social life; but that in course of time people lost sight of the moral, and believed the fiction in its literal sense.

The oldest collection of fables in any European language is in Greek prose: the fables are attributed to Æsop, but much doubt exists as to the real author or authors of them. [ÆSOPUS, IN BIOG. DIV.] Babrius wrote a metrical version of Æsopian fables, some of which were used as materials for prose versions of the Æsopian fables by the mediæval writers; a few were always common, and a large addition to them was recovered by Minoides Minas, and published in Paris in 1842. [BABRIUS, IN BIOG. DIV.] The fables called the fables of Bidpai or Pilpay [PILPAY, IN BIOG. DIV.] are derived from a collection in the Sanscrit language, and Lokman is said to have written fables in Arabic; but several of the fables attributed to the latter appear to be the same as some of those attributed to Æsop, and it has been supposed that Lokman and Æsop were one and the same personage. [LOKMAN, IN BIOG. DIV.]

Among the Latins, Phædrus, who lived under Tiberius, is the most celebrated: he professes to have taken his subjects from Æsop. The MS. of Phædrus was not discovered before the end of the sixteenth century. Avianus, or Avienus, who (supposing the two names to mean the same individual) lived under the elder Theodosius, wrote a collection of fables in Latin verse. ('Avienus,' Leyden, 1731, with a 'Dissertation on the Identity of Avianus and Avienus.') Faerno of Cremona, who lived about the middle of the sixteenth century, made a collection of Æsopian fables, which he turned into Latin verse, and which were published at Rome after his death in 1564. He was accused of plagiarism, as having found a MS. of Phædrus in some library, and borrowed his subjects from it. The fables and fable narratives of the middle ages have been well described, and their characteristics discussed, by Jacob Grimm, in a preface to his edition of 'Reinhart Fuchs,' published in 1840.

Among the original writers of fables or apologues, in the modern languages, La Fontaine may be fairly placed at the head. Among the English, Gay and Moore have written fables. The Germans have had Lessing, Gellert, and others, and the Spaniards Yriarte and Samaniego. Among the Italians, Firenzuola, Crudeli, Baldi, Capaccio, in the 16th and 17th centuries, wrote chiefly translations or paraphrases from the Greek and Latin fabulists. In the 18th century Pignotti, a native of Tuscany, wrote original fables in verse, which were published at Pisa in 1782, and have been often reprinted since. Bertola also wrote fables (Pavia, 1788), with an essay on fables. Luigi Fiacchi published, under the name of 'Clasio,' a collection of fables (Florence, 1807).

FAÇADE, in architecture, a French term of modern introduction into the English language. It expresses the face or front view of an edifice, as the façade of the Louvre, or the façade of St. Peter's at Rome. Façade was applied originally to denote the principal front of a building. The Italians apply the term Facciata for the most part to such fronts as have a principal entrance.

FACIA, a term used in architecture, or in ornamental construction, to express the subordinate bands of an architrave or of a frieze. It is worthy of notice that in the best examples of Grecian or of Roman architecture the facias are made to incline inwards from the vertical line; as, for instance, in the Parthenon, the temple of Bacchus at Rome, the Baths of Diocletian, and the temple of Vesta at Tivoli. The facias of the architraves of the temple of Mars Ultor, and of the Forum of Nerva, incline outwards; but the optical effect thus produced is so unsatisfactory that it may almost be considered to be indispensable that the more general rule should be observed.

FACTOR is a mercantile agent who buys and sells on behalf of others, usually being intrusted with possession of the goods, to deal with them in his own name, and to receive and give receipts for the money, and is remunerated for his services by a percentage on the transaction. A broker acts as a middleman only, having no possession of the goods, and properly negociating the business in the name only of his principal; the price does not pass through his hands, but he too is remunerated for his assistance by a percentage on the transaction.

No small share of the business of the mercantile world is carried on through the medium of factors, living at a distance from their principals; whom for their own interest they keep duly informed of the state and prospects of the market in their immediate district; and from whom they accordingly receive consignments, often remitting their acceptances for the same in advance, on the expectation that future sales will put them in sufficient funds to retire their acceptances when due. As these transactions multiply, the relation of principal and agent becomes more complicated in interest, and a clear and complete statement of credits and debits on his principal's account is one of the most essential duties of the factor, which a court of equity will compel him to render, if need be, and for want of which, when refused, an action for damages will lie against him at common law.

The law gives him a lien upon the property in his hands for the general balance, composed of advances, expences, and commission, due from his principal; and the produce of sales, as well as the goods before sale, are subject to this lien. He may therefore think it prudent for his own behalf to effect an insurance on the property of the principal in his hands; and unless he is expressly forbidden he may insure in his principal's name, and at his expense; but if the principal requires him to do so, it then becomes his duty, and negligence as to that might leave him answerable for the consequences of accidental fire. He has an interest obviously in keeping the property safe. The law imposes on him the duty of exercising ordinary care and diligence for its protection, but if there is no failure therein upon his part, he is not liable for damage happening to it through violence or accident, as by robbery, or fire, which a prudent, careful man under the circumstances could not have prevented.

In his transactions about the goods of his principal in the market he is bound by the usage of trade, when that is not expressly negatived by his instructions. If it is not usual therefore to sell on credit, and if he yet does so, he is answerable for the consequences of this deviation from his authority. In other respects he is bound to exercise ordinary skill, caution, and diligence, in the discharge of his duties as factor.

By the common law of this country the factor has no authority to pledge the goods of his principal. The disadvantage of this rule with regard to a class of agents who are in the daily habit of binding themselves by their acceptances in favour of the principal, in dependence upon the market and their ability to realise the goods in time to meet the bills at maturity, became so obvious, that the British legislature twice interfered by statute, the 6 Geo. IV. c. 94, and the 5 & 6 Vict. c. 39, to place these agents, in this respect, upon a footing suitable to the necessities of trade and the dictates of prudence. The results of this legislation now are, that a factor may pledge goods or documents of title in his possession for advances to himself, with security to the lender, provided the advances, which must not include an antecedent debt, were bonâ fide, and that the lender had no notice of the pledge being contrary to the factor's authority, or made *malâ fide* in respect of his principal. If the loan is made on a written contract to deposit goods, a pledge in accordance therewith is protected, unless the lender have notice of the factor's want of authority prior to the receipt of the goods; and even an antecedent debt is a good consideration for the pledge to the extent of the factor's lien against the principal, if the pledgee at the time did not know of the factor's agency. Goods or documents of title already on pledge may be replaced by other goods or documents of title in the hands of the pledgee, subject to the continuing lien. Documents of title are now said to be intrusted to the factor, so as to entitle him to pledge them whether they come immediately from the owner or in virtue of his having had possession of the goods or of some other documents of title before.

A sale by a factor creates a contract between his principal and the buyer, and the principal may maintain an action against the purchaser for the price, or by notice may direct him not to pay the money to the factor, which is binding on the purchaser, except in so far as the factor has a lien upon the money against his principal. In the absence of any such notice payment to the factor is a good discharge of the debt. By a purchase through a factor in his own name the seller has the option, as soon as he knows the name of the principal, of taking either the factor or his principal as his debtor in the transaction. But if a bargain is effected with a factor under the opinion that he is a principal, and with a view to a right of set-off which the other has against him, the disclosure of the real principal is not suffered afterwards to deprive the other of his right of set-off.

The principal may recover against his factor by action for the neglect of his duty, or disobedience to his instructions if loss occur thereby, as if he purchases goods at a limited price, and fraudulently sells them again for his own profit. If a factor, without the orders of his principal, exports goods prohibited by the Customs' laws, and the same are seized, the loss is the factor's; and so, if he pay money without the direction of his employer, or sells his goods at an undervalue, or exports goods of an improper quality, he is answerable for the damage. And if a factor exports goods of a different quality or kind from those he was directed to purchase, or sends them to a place other than that to which he was ordered to send them, the merchant may refuse to accept them, and may recover any damage he has sustained, in consequence of his neglect, from the factor. The rights and liabilities of merchants and factors are governed by the laws of the place in which they are domiciled, and any contract which may be made by either of them must be governed by the law of the place where it is made, and these rules are acted upon by the courts of justice of every civilized nation. Thus, since the passing of the above-mentioned statutes, a foreign merchant cannot recover his goods from the pledgee of his factor in England, though he be totally ignorant of the change which has taken place in the law.

There is another description of factor, who acts under what is called a del credere commission, where, for an additional percentage, he engages for the solvency of the purchasers of the goods consigned to him. This contract, it is evident, arises on the supposition that the factor being resident among the purchasers, must be better able to judge of their solvency than the principal, residing in a foreign country. For a long time it was considered that under this arrangement those who dealt with the factor were liable to him alone, and that he was liable, in the first instance, to his employer; it has, however, been decided that the factor stands in the relation of a surety for the persons with whom he deals on account of the employer, and that he is liable to his employer only in case of their default. Del credere is an Italian mercantile phrase, of the same signification as the English word guarantee, and the Scotch warrandice.

(See Russell on *Factors;* Story on *Agency; Id.* on *Bailments;* Sir Wm. Jones on *Bailments;* Paley on *Principal and Agent;* Chitty on *Contracts*, by J. A. Russell.)

FACTOR, a name given to any algebraical expression considered as part of a product. Thus, a and $a+x$ are the factors of the product $a\,(a+x)$, or $a^2+a\,x$.

Any quantity may be made an apparent factor of any other. Thus in

$$a = b \times \frac{a}{b}$$

b is an apparent factor of a. But b is not properly called a factor of a, unless it happen that when b is made $= 0$, $\frac{a}{b}$ is not thereby made infinite. Thus the two equations

$$\sin x = x \times \frac{\sin x}{x}\,, \quad \sin x = x^2 \times \frac{\sin x}{x^2},$$

show x and x^2 as apparent factors of $\sin x$. But x is a real factor; x^2 is a fictitious factor. When

$$x = 0,\ \frac{\sin x}{x} = 1, \text{ and } \frac{\sin x}{x^2} = \infty.$$

FACTORIALS. The subject treated under this word is one which daily becomes of more importance in mathematical analysis, and takes its rise at the commencement of algebra.

When we first begin to number, we easily make the transition from integers to fractions, because we are accustomed to consider ourselves as reckoning simple magnitude, of which each unit can be divided into parts homogeneous with itself. [NUMBER.] Be the unit what it may, in the case of simple magnitude, it might as well have been any fraction of what it is, so far as the possibility of conceiving and performing arithmetical operations is concerned. But when we come to count *operations*, not *magnitudes*, the case is much altered; we can no longer say at pleasure that we can conceive or introduce fractions. Certainly, as to additions, we think we need not stop to learn what a fractional number of them means. If, after having thought for a moment of six additions of 20 and seven additions of 20, we ask ourselves what ought to be meant by *six and a half* additions of 20, we imagine that it must necessarily mean six additions of 20, followed by an addition of 10. But this notion, though the most simple, and therefore adopted as a basis, is not necessary. The algebraist knows very well that having proved the equation $\phi(x, m) = x + mb$ to be true whenever m is an integer, he has not proved it to be true when m is a fraction: in fact, $\phi(x, m) = x + mb \cos 2m\pi$ would equally satisfy his demonstration, and an infinite number of other solutions might be named.

When we come to reckon numbers of multiplications, we begin from unity, and say, let a^n signify that unity is multiplied n times following by a. Now this symbol is, from the beginning, distinctly conceivable, whether a be integer or fractional, under the usual and easy extension to fractions of the idea of multiplication; but it is not, or ought not to be, so intelligible when n is a fraction. What are four and a half multiplications by 36? The beginner will say, four multiplications by 36, followed by a multiplication by 18; but this mode of defining breaks down immediately, for the two half operations would make more than the whole: two successive multiplications by 18 are equivalent to more than a multiplication by 36. It is multiplication by 6 which is the *half operation* to multiplication by 36. It is true that we do not apply the phrase *fraction of an operation* in our descriptive language; but we apply the symbol in our symbols. For just as every a^1 in a^n denotes one multiplication by a, every $a^{\frac{1}{2}}$ denotes that multiplication which twice repeated is equivalent to one multiplication by a. In like manner $a^{\frac{3}{7}}$ is the multiplier which being used 7 times, gives the same result as a used 3 times. We are not going to give the theory of simple powers, but only to put it in connection with what follows; and the reader will do well to observe, that in the very first ideas of ratios [ADDITION OF RATIOS] the notion of numerical quantity entering as a multiplier in repeated operations was so much in the minds of those who framed Euclid's language, that they spoke of what were really multiplications as if they had been additions. The same thing may be traced in calling 100 to 1 the duplicate ratio of that of 10 to 1 [RATIO], and 10 to 1 the subduplicate ratio of that of 100 to 1: duplicate means double, and subduplicate means half. The beginner must learn to understand numbers with reference to their force as indices of operation, and even the advanced student may require more study of this part of the subject than he suspects himself wanting.

Again, to establish the equation $\phi(x, m)=x^m$ when m is an integer, is not the same thing as establishing

$$\phi\left(x, \frac{m}{n}\right)=\sqrt[n]{x^m}:$$

in fact the symbol $x^{\frac{m}{n}}$ in algebra is well known [ROOT.] to be in its complete meaning

$$\sqrt[n]{x^m}\left\{\cos\frac{m}{n}.2k\pi+\sqrt{-1}\sin\frac{m}{n}.2k\pi\right\}$$

where k is any integer.

Next after the operations of powers and roots, nothing occurs more frequently in mathematical formulæ than successions of multiplications in which the multiplier is not always the same, as $1 . 2 . 3 \ldots . n$, $a(a+b)(a+2b) \ldots . (a+\overline{n-1}b)$. The various hints which had been given of the interpolation of fractional meanings, such as that of Wallis, and others of Leibnitz, the Bernouillis, Stirling, &c., have been extended with great power by the French and German mathematicians of the last eighty years. Two different lines were taken in the two countries. The Germans first began to consider how the ordinary notation might be extended. Vandermonde proposed to denote $m(m-1)(m-2) \ldots .$ to n factors by $[m]^n$; the brackets distinguishing it from m^n in the usual sense. Hindenburg, followed by Kramp and most of the Germans, proposed a much better notation. Considering x^m as denoting m unaltered factors, they made room in the symbol for a part expressive of the permanence of the factor, and wrote it $x^{m|0}$. Thus it became a particular case of $x^{m|a}$, which was made to stand for m factors, the first of which is x, and which alter by a at every step; giving

$$x^{m|a}=x(x+a)(x+2a) \ldots\ldots (x+\overline{m-1}a)$$

$$x^{m|-a}=x(x-a)(x-2a) \ldots\ldots (x-\overline{m-1}a)$$

$$(x+\overline{m-1}a)^{m|-a}=x^{m|a}$$

$$1^{n|1}=1 . 2 . 3 \ldots\ldots n=n^{n|-1},$$

and so on. This notation certainly opens the road to convenient expression of a large number of striking formulæ: take its binomial theorem for instance,

$$(x+y)^{n|a}=x^{n|a}+nx^{n-1|a}y^{1|a}+n\frac{n-1}{2}x^{n-2|a}y^{2|a}+\ldots$$

which is perfectly analogous to the ordinary theorem.

Also the following:—

$$(1+\mathrm{A}^{1|a}x+\mathrm{A}^{2|a}\frac{x^2}{2}+\mathrm{A}^{3|a}\frac{x^3}{2.3}+\ldots)^m=$$

$$1+(m\mathrm{A})^{1|a}x+(m\mathrm{A})^{2|a}\frac{x^2}{2}+(m\mathrm{A})^{3|a}\frac{x^3}{2.3}+\ldots\ldots$$

which is true for all values of m, and gives the binomial theorem if $\mathrm{A}=1$, $a=-1$, and the exponential theorem if $\mathrm{A}x=1$, $a=0$. The analogous theorem to Taylor's is

$$\phi(x+h)=\phi x+\frac{\Delta\phi x}{\Delta x}h^{1|-\Delta x}+\frac{\Delta^2\phi x}{\Delta x^2}\frac{h^{2|-\Delta x}}{1.2}+\ldots .$$

which is well known.

We think it is to be regretted that this notation has not been more adopted in England: we do not remember at this moment any writer who has made much use of it, except Mr. Peter Nicholson, in his works on Involution and on Increments.

A name was to be found for this extension. The notion of calling x^2, x^3, x^4, &c. the *powers* of x, was an extension of the term as used by Euclid, which applied to the square on a line only. Not that the square on a line was originally called its power, but that the power of a line was measured by the capacity of its square. The object of the old geometers was to reduce every area to a square, which enabled them to describe it by one line; and hence a line seems to have been considered as having more or less power (of inclosing space) according as its square was greater or less: the power being measured by the magnitude of the square. The phraseology seems to have reached those who were not geometers: thus Diogenes Laertius tells us that Pythagoras discovered that * the 'subtending side of a right-angled triangle is as powerful as the two containing sides together.' But those who will smile at the idea of the power of a line residing in its square, will laugh outright at the notion of Kramp, who proposed, seeing x^a represents the *powers* of x, that the symbol $x^{a|a}$ should represent its *numerical faculties* (facultés numériques). From the powers and the faculties we might have reached, possibly, the feelings and opinions, had it not been for Arbogast, who proposed to call the different cases of $x^{a|a}$ by the name of *factorials*, a term which has now gained considerable currency among the German writers, and was approved by Kramp himself.

The French, on the other hand, follow Euler and Legendre in connecting the factorials from the outset with definite integrals, and the latter in adopting a specific notation, not derived from that of powers. Legendre signifies $1 . 2 . 3 \ldots . n$ by $\Gamma(n+1)$, and hence the name of *gamma-functions* has been applied to them: they are best called *factorial functions*.

We shall give a slight account of the subject so far as it is in the way to be speedily reckoned among the elementary parts of mathematics.

A series or a product of n terms is only distinctly conceivable when n is integer, but if it can be represented by a function in which n enters as a usual symbol of magnitude, and not as a number of terms or operations, then the function is intelligible, though not the representative of the series, when n is a fraction. To take a very simple case: it would be absurd to demand the value of $1+2+3+\ldots\ldots+(n-1)+n$, when n is a fraction; but this series is $\frac{1}{2}n(n+1)$, which is always intelligible.

The equation

$$1+2+3+\ldots\ldots+n=\tfrac{1}{2}n(n+1)$$

is absurd except when n is a positive integer. In the times when the phrase 'less than nothing' was invented, it would have been said boldly that $2\frac{1}{2}$ terms of this series are $\frac{1}{2}\times 2\frac{1}{2}\times 3\frac{1}{2}$, or $35\div 8$, and that -7 terms of it are $\frac{1}{2}(-7)(-6)$ or 21. All that we should now say is that the function which, when n is integer, is equal to $1+\ldots\ldots+n$ becomes $35\div 8$, and 21, when n is $2\frac{1}{2}$ and -7. Whether we are likely to be the gainers by refusing extensions of language which naturally present themselves, remains to be seen: it seems to us that '-7 terms of the series $1+2+\ldots+n$' is a very innocent abbreviation of 'the value, when $n=-7$, of the function which, when n is a positive integer, is always equal to $1+2+\ldots+n$.' But at any rate, mathematicians are now in the habit of passing from expressions in which n is an index of number of operations, to the equivalents in which n is only an index of magnitude, and of using the latter in the most general sense.

But there is an infinite number of ways of representing, for example, a function which is $1+2+\ldots .+n$ when n is an integer. If ϕn be a function which is unity whenever n is an integer, such as $\cos 2\pi n$, $1+\sin 2\pi n$, &c., then $\frac{1}{2}n(n+1)\times\phi n$ answers the condition as well as $\frac{1}{2}n(n+1)$. It is usual however to start with a radical function which is free from periodic multipliers, and there is generally no difficulty in deciding upon the selection. In all the cases which are most useful, the radical function is the one which is clear of all sines and cosines.

But it is to be remembered that in this branch of the subject we have not advanced so far as to make it coextensive with the theory of powers: it is in fact precisely in the condition of the theory of powers before the discovery of the multiplicity of values in x^n when n is fractional. We are thus limited to an arithmetical view of the subject.

Some writers have censured Legendre for employing a new symbol $\Gamma(n+1)$, when $1^{n|1}$ was already in use: if, which may be doubtful, he had heard of the latter before he invented the former, he would, in our opinion, still have acted judiciously in inventing the additional symbol. He might have argued that it would not be wise to associate the second symbol with notions which are only true of the arithmetical case of it. As soon as the complete theory of the expression shall be given, $1^{n|1}$ is ready for it: in the mean while $\Gamma(n+1)$ expresses the arithmetical case of it, just as $\sqrt[n]{x^m}$ expresses that of $x^{\frac{m}{n}}$.

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* We translate quite literally, to show that Laertius was not geometer enough to know that the subtending and containing was said of the *right angle*, not of the *triangle*. His words are ἴσον δύναται which Kraus, who in his turn was not geometer enough to venture the rendering of ὀρθογώνιον into Latin, translates *tantundem valere*. We take Laertius as meaning that the hypothenuse was as powerful as the two sides together: whether he understood his own phrase, or only caught it from the geometers, is another question. For othe uses of the same phrase, see IRRATIONAL.

The following are some of the cases which are strictly intelligible when n is an integer, and in which the radical function remains intelligible when n is fractional :—

$$1+\tfrac{1}{2}+\tfrac{1}{3}+\ \ldots\ +\tfrac{1}{n}=\int_0^1 \frac{1-v^n}{1-v}\,dv$$

$$1\times 2\times 3\ \ldots\ \times n=\int_0^\infty \epsilon^{-v}\,v^n\,dv$$

$$p\,(p+q)\ldots(p+\overline{n-1}\,q)=q^n\,\frac{\int_0^\infty \epsilon^{-v}\,v^{\lambda+n-1}\,dv}{\int_0^\infty \epsilon^{-v}\,v^{\lambda-1}\,dv}$$

where $\lambda=p\div q$.

The second equation, which may be thus written,

$$\Gamma\,(n)=\int_0^\infty \epsilon^{-v}\,v^{n-1}\,dv$$

is the most important. The following are its principal properties :

1. Γn is finite when n is positive, but is infinite when n is 0 or negative. This draws a great distinction between it and $1^{n|1}$; for the general formula which connects factorials of positive and negative exponents, with a common augment, is

$$x^{-n|a}\times(x-na)^{n|a}=1$$

Γn, which is infinite when $n=0$, diminishes from thence very rapidly, becomes 1 when $n=1$, and thence further diminishes until $n=1{\cdot}461632\ldots$, when it is least, being then $\cdot 8856032\ldots$. From thence it begins to increase, being 1 again when $n=2$, 1.2 when $n=3$, 1.2.3 when $n=4$, and so on.

2. The equation $\Gamma(n+1)=n\Gamma n$, so obviously true when n is an integer, is always true ; giving also

$$\Gamma(n+1)=n\,(n-1)\ldots\ldots(n-m)\,\Gamma\,(n-m)$$

for every integer value of m. Hence a table of values which extends through one unit is sufficient : and the most convenient interval is that from $n=1$ to $n=2$. If, for instance, we wanted to calculate from such a table the value of $\Gamma\,(5\tfrac{1}{3})$ we should reduce it to $4\tfrac{1}{3}\times 3\tfrac{1}{3}\times 2\tfrac{1}{3}\times 1\tfrac{1}{3}\times\Gamma\,(1\tfrac{1}{3})$, and take $\Gamma(1\tfrac{1}{3})$ from the table. Similarly Γn, when n is less than unity, would be found from $\Gamma\,(1+n)\div n$. When n is very small, Γn is $1\div n$ nearly.

3. The labour of calculating the table is much lessened by the following equation :—

$$\Gamma n\times\Gamma(1-n)=\frac{\pi}{\sin n\pi}$$

which is true when n lies between 0 and 1. One very useful result of it is $\Gamma\tfrac{1}{2}=\sqrt{\pi}$.

4. There is a constant to be introduced, which we shall call γ, the importance of which may in time compete with that of π and ϵ. It is the limit of the expression $1+2^{-1}+3^{-1}+\ldots+x^{-1}-\log x$, as x is increased without limit : it is also the value of

$$\int_0^1\left\{\frac{1}{1-v}+\frac{1}{\log v}\right\}dv \text{ and of } -\int_0^\infty \epsilon^{-v}\log v\,dv\,;$$

its value is

$$\gamma=\cdot 57721566490153286060 65\ldots$$

5. If S_n represent $1^{-n}+2^{-n}+3^{-n}+\ldots\ldots$ ad infinitum (See SUMMATION, for some of the values ; also 'Differential Calculus,' 'Library of Useful Knowledge,' p. 554), the logarithm (Naperian) of Γx may be found in either of the following ways :—

$$\log\Gamma(1+x)=-\gamma x+\frac{1}{2}S_2x^2-\frac{1}{3}S_3x^3+\frac{1}{4}S_4x^4-\ldots\ldots$$

$$=\frac{1}{2}\log\left(\frac{\pi x}{\sin\pi x}\right)-\tfrac{1}{2}\log\left(\frac{1+x}{1-x}\right)$$

$$+(1-\gamma)x-\frac{1}{3}(S_3-1)x^3-\frac{1}{5}(S_5-1)x^5-\ldots$$

$$=\frac{1}{2}\log(2\pi)+\left(x+\frac{1}{2}\right)\log x$$

$$-x+\frac{1}{12x}-\frac{1}{360x^3}+\ldots$$

6. A table of the values of comm. log. $\Gamma(1+x)$ is given by Legendre for every thousandth of a unit from $x=\cdot 000$ to $x=\cdot 999$: an abridgment of this table, with means of completing it, is in the 'Diff. Calc.,' 'Library of Useful Knowledge,' p. 587. This function Γx is a fundamental mode of expression for the results of large classes of definite integrals. [INTEGRALS, DEFINITE.]

7. The function $\Gamma(n+1)$ is the value, or one of the values, of $1^{n|1}$, and we have

$$p^{n|q}=q^n\,1^{\frac{p}{q}+n-1|1}\div 1^{\frac{p}{q}-1|1}$$

$$=q^n\,\Gamma\left(\frac{p}{q}+n\right)\div\Gamma\left(\frac{p}{q}\right)$$

which holds whenever the second side is real and finite.

The student who desires to know more of the theory may consult Kramp's 'Analyse des Réfractions Astronomiques,' Strasburg, 1799, 4to., and the article 'Factorielles,' in the Supplemental (or third) volume of Montferrier's 'Dictionnaire des Sciences Mathématiques,' Paris, 1840, 4to. Also the article 'Facultat' in Grunert's Supplement to Klügel's 'Worterbuch der Reinen Mathematik,' Leipzig, 1836, 2 vols. 8vo. On the form Γx see Legendre's well known works, the 'Exercices du Calcul Integral,' and that on Elliptic Functions. Some of the substance of these is in the treatise on the 'Differential Calculus', in the 'Library of Useful Knowledge.'

FACTORIES; FACTORY-SYSTEM. The word factory has had two different meanings. It formerly meant an establishment of merchants and factors resident in foreign countries, who were governed by certain regulations adopted for their mutual support and assistance against the undue encroachments or interference of the government of the countries in which they resided. In modern times these factories have, in a great measure, ceased to exist; because of the greater degree of security which merchants feel as regards both the justice of those governments and the protection, when needed, of their own country. The Venetians, Genoese, Portuguese, Dutch, French, and English have all had establishments in the nature of factories. In China the Portuguese established a factory at Macao, and the English at Canton. In most instances factories have at first obtained the privilege of trading, and afterwards procured for the precinct assigned to them some exemption from the jurisdiction of the native courts. In this state of things the supreme government of the country whose subjects have established the factory prepare laws for its control and administration, and treat it in fact as if it were its dependency, though the sovereignty of the native government is undisputed.

But in its usual acceptation, the word factory has now a different meaning. Modern legislation has declared that a factory means any building wherein steam, water, or other mechanical power is used to work any machinery employed in the manufacture of cotton, wool, hair, silk, flax, hemp, jute, or tow.

What is called the Factory System owes its origin to the inventions and skill of Arkwright; and it is probable that but for the invention of spinning machinery, and the consequent necessary aggregation of large numbers of workmen in cotton-mills, the name would never have been thus applied. It is in these mills that the factory system has been brought to its highest state of perfection. The power of subdivision of employment according to strength and skill, and that of bringing to bear upon every distinct process exactly as much force as is necessary, without waste, are the two great and valuable advantages of the factory system. The cotton-mills, and some of the circumstances connected with them, are noticed under COTTON MANUFACTURE.

The legislature has interfered to prevent children in factories from being tasked beyond their strength, to the permanent injury of their constitutions. This abuse was the more to be apprehended, because a large proportion of the children engaged in cotton-spinning are not directly employed by the masters, but are under the control of the spinners—a highly paid class of workmen, whose earnings greatly depend upon the length of time during which they can keep their young assistants at work. A parliamentary committee sat for the investigation of this subject in 1832, and subsequently a commission was issued by the crown for ascertaining, by examinations at the factories themselves, the kind and degree of abuses that prevailed, and for suggesting the proper remedies. In consequence of these inquiries, an act was passed in 1833 for regulating factories. Attempts had been made in 1802, 1816, and 1831, to legislate for the protection of factory workers; but only on a small scale.

The Act of 1833 (3 & 4 Will. IV. c. 103) contains numerous details; but the chief matters that relate to the subject are the following:—1. After January 1, 1834, no person under 18 years of age shall be allowed to work in the night, that is, between a quarter past eight P.M. and half-past five A.M., in any cotton or other factory in which steam or water, or any other mechanical power, is used to propel the machinery, except in lace factories. 2. No person under 18 shall be employed more than 12 hours in one day, nor more than 69 in one week. 3. There shall be allowed in the course of every day not less than 1½ hours for meals to every person restricted to the performance of 12 hours' work. 4. After January 1, 1834, no child shall be employed under 9 years of age, except in silk-mills. 5. After March 1, 1834, no child, except in silk-mills, shall be employed in any factory more than 48 hours in any one week, nor more than 9 hours in any day, who shall not be 11 years old; nor after March 1, 1835, who shall not be 12 years old; nor after March 1, 1836, who shall not be 13 years old; and these hours of work shall not be exceeded, even if the child has worked during the day in more factories than one. 6. Children and young persons, whose hours of work are regulated, shall be entitled to two holidays and eight half-holidays in the year. 7. Children, whose hours of work are restricted to 9 hours a day, are not to be employed without obtaining a certificate from a physician or surgeon, certifying that they are of the ordinary strength and appearance of children of the ages before mentioned, which certificate is to be countersigned by some inspector or justice. 8. The crown is to appoint, during pleasure, four persons to be inspectors of factories, with extensive powers as magistrates, to examine the children employed in the factories, and to inquire respecting their condition, employment, and education; and one of the secretaries of state shall have power, on the application of an inspector, to appoint superintendents to assist in carrying out the provisions of the act. 9. The inspectors are to make all rules necessary for the execution of the act, and to enforce the attendance at school, for at least two hours daily out of six days in the week, of children employed in factories; from whose weekly wages a deduction, not exceeding a penny in every shilling, is to be made for the expense of schooling. 10. No child shall be employed who shall not, on Monday of every week, give to the factory master a certificate of his or her attendance at school for the previous week. 11. The interior walls of every factory shall be whitewashed every year. 12. A copy or abstract of the act shall be hung up in a conspicuous part of every factory. 13. The inspectors shall regularly, once a year, report their proceedings to one of the secretaries of state. There are other clauses regulating the hours of working in mills where the use of water-power instead of steam-power disturbs the uniformity of the working; the steps to be taken in order to obtain regular certificates of age for the children requiring them; the erection of schools, where necessary; and the mode of enforcing the provisions of the act.

In the following year a short explanatory act was passed, to render more clear the meaning of the legislature on certain points; but with this exception, no further change was made till 1844. Committees of the House of Commons sat in 1840 and in 1841, and bills were from time to time introduced by individual members; but the Act of 1833 remained the groundwork of all the proceedings in respect to factories. The Act itself was, as we have already stated, in great part the result of a commission which had been appointed in the early part of 1833, and which had collected information by means of district commissioners in all the factory districts. This local machinery formed a groundwork for the inspectorship afterwards established by the government when the act was obtained. Four inspectors were appointed, and the British Islands were mapped out into four great divisions; the cotton and woollen district of Yorkshire, Lancashire, and the immediate neighbourhood, forming the 1st; the eastern and southern counties of England the 2nd; some parts of the West of England, nearly the whole of Wales, and the southern half of Ireland, constituting the 3rd; the northern half of Ireland, the whole of Scotland, and the four northern counties of England, the 4th. Each district was placed under one inspector, who made arrangements for becoming personally acquainted with every factory in his district employed for textile manufactures. Surgeons were appointed to grant the certificates required for the children; a system of occasional supervision was established; the inspectors communicated with the chief mill-owners on any points of difficulty which occurred; and the schooling of the children was gradually entered upon. One great difficulty however was this, that many manufacturers, as a means of escaping from the provisions of the Act, gradually discharged the children who were within the specified ages, and employed others of an age to which the education and the working-hours clauses did not apply; and many young children were thrown out of employ in consequence.

The Act rendered imperative some sort of schooling for the factory children; but it did not lay down rules for its government. The arrangements accordingly became of a very crude and heterogeneous character. The factory children received their education from five different sorts of schools, *Sunday Schools, Dame and Private Schools, Factory Schools, Church of England Schools*, and *Dissenters' Schools.* The disposal of the children on Sundays was a matter which did not come under the control of the inspectors; but the four classes of week-day schools were those which affected the daily regulations of the factories. The dame-schools or private schools, kept by mistresses or masters for their own profit, and not under the control or management of any other person, were of a very mean and inefficient kind, utterly wanting, in respect to instruction, books, and discipline, in the means of working out the required object. The factory-schools were such as were held in or near the factory where the children were employed, and were under the control and management of the owner of the factory. The Church Schools and the Dissenters' Schools, supported in many cases by powerful religious denominations, partook of the general character of such classes of schools, in respect to education and discipline. Many of the factory-schools, where the owner cared very little about the matter, were as bad as the dame-schools; whereas, in some cases the mill-owners took great interest and expended considerable sums in giving efficiency to the schools. At Messrs. Marshall's, at Leeds, for instance, a neat building was erected purposely as a school-room for the factory children, admirably fitted with every requisite for a large school.

In 1844 an Act was passed (7 & 8 Vict. c. 15) which came into operation in October of the same year, and effected certain changes in the law as to factories. An Office of Factory Inspectors was established in London. Persons beginning to occupy a factory were required to send notice of it to this office. The powers of inspectors to enter factories and schools are increased. The certifying surgeons are to be appointed by the inspectors; and the certificates are to have a definite form and expression. The whitewashing or painting of a factory is placed under strict regulations. Provision is made for the protection of children from the effects of the water in wet-flax spinning, and from accidents by the machinery while in motion. Children may be admitted and employed at eight years of age (the former minimum having been nine years). The maximum amount of daily work for each child is seven hours, subject to diminution in certain cases. All females are regarded in the same light as "young persons" (that is, persons from thirteen to eighteen years of age), as to the limitation of the hours of work. The recovery of lost time by the stoppage of machinery, the regulation of the meal-times in the factories, the holidays given to the children, the control of their attendance at school, the inspection of dangerous machinery, and many other points, are modified or extended in this Act; which however preserves the general character of the Act of 1833.

Before touching on the legislation of later years, we will present a few statistics of factories. The number of power-looms employed is to a certain degree, an index to the extent of factory operations; since the substitution of a power-loom for a hand-loom involves the substitution of a large and well-organised factory for, perhaps, the humble cottage of the hand-loom weaver. In a return made to government in 1836, the number of power-looms then employed is stated to have been about 92,000. There was another return concerning the number of factories, and of the persons working therein, in the same year; this gave about 304,000 persons in about 2860 mills, or 106 to each. By the commencement of 1839 the numbers had thus risen:—420,000 persons in about 4200 mills, or 100 to each. A return for 1843 gives a series of numbers under three different points of view; the first being according to the kind of textile material; the second, according to the location in different parts of the empire; and the third, according to the ages and sexes of the workpeople.

	No. of Factories.	Horse-power employed.	Persons employed.
Cotton . .	1,819	65,785½	259,385
Wool . . .	1,738	15,564½	86,446
Silk . . .	268	2,977	34,318
Flax . . .	392	9,585	43,487
Total . .	4,217	93,912	423,636
England . . .	3,475	77,804½	347,007
Scotland . .	492	12,448½	59,313
Ireland . . .	95	3,001	14,870
Wales . . .	155	657½	2,446
Total . . .	4,217	93,911½	423,636
Males under 21			100,654
Males 21 and above			77,999
Females under 21			163,252
Females 21 and above			81,566
Total			423,471

It may be well to remark that these numbers relate to the workpeople actually employed within the factories at one or other of the above four kinds of textile manufacture. The whole number who earn a living by these trades, including those engaged in hand-loom weaving, stocking-making, calico-printing, dyeing, bleaching, &c., very greatly exceeds the above, and has been variously estimated by different writers.

In 1845, Mr. Horner, whose district was very nearly co-extensive with Lancashire, gave the following as the state of his district in that year:—

	Mills.	Workers under 18.	Workers 18 & above.	Power Looms.
Cotton mills . .	1,724	69,155	128,305	138,717
Woollen mills . .	241	5,456	6,485	3,237
Flax mills . .	71	2,255	3,336	..
Silk mills . . .	32	3,121	3,324	995
Total .	2,068	79,987	141,450	142,949

The great strength of the woollen and worsted trades lay in another district, concerning which similar returns were not made.

In September, 1848, the mills and works within the limits of the town of Manchester, subject to the factory laws, were as follow:—

	Mills.	Hands.
Cotton	96	26,809
Silk	8	2,850
Worsted	3	169
Small wares	17	1,752
Print works	4	1,172
Dye works	23	1,847

In 1850 a return was made to the House of Commons respecting factories, more detailed and instructive than any before prepared. We will give a few of the results, calculated to illustrate different aspects of the subject. First, in respect to different parts of the United Kingdom, we have,—

	Factories.	Spindles.	Power Looms.	Horse Power.	Children employed.	Total employed.
England and Wales . .	3,680	22,850,010	272,588	109,824	34,155	495,707
Scotland . .	550	2,256,463	23,811	19,861	929	78,688
Ireland . . .	91	532,503	2,517	4,532	38	21,687
Total	4,330	25,638,716	298,916	134,217	35,122	596,082

In this table, the *horse-power* includes both steam-engines and water-wheels employed in working the machinery in the factories; they are nearly in the ratio of four-fifths steam-power to one-fifth water-power. The term *children* is applied to those at and under 13 years of age; from 13 to 18 the term applied is *young persons*. Taking the whole of the United Kingdom in one entry, and regarding only the ages and sexes of the persons employed, we find the following numbers:—

	Males.	Females.		
Under 13 . .	19,400	15,722	=	35,122
13 to 18 . .	67,864	329,577	=	555,307
Above 18 . .	157,866			
Total . .	245,130	345,299	=	590,429

In respect to females, one entry includes *young persons* and *adults*, as the same laws now apply to both classes. Of 100 persons working in factories, 58 are females and 42 males. About 6 per cent. of the workers are under 13 years old. The next classification we shall notice is that which depends on the kind of operations carried on. There are four classes, as follows:—

Spinning factories	2636
Weaving factories	454
Spinning and weaving factories	1005
Not specified	505
	4600

The five principal kinds of materials employed in the factories, and the persons employed in them, are distributed as follows:—

		Persons.
Cotton factories	1,932	330,924
Woollen factories	1,497	74,443
Worsted factories	501	79,737
Flax factories	393	68,434
Silk factories	277	42,544
	4,600	596,082

The number of factories here given (4600) is in excess of that given in the first table (4330); this probably arose from some of the factories being entered twice, in cases where they worked *mixed fabrics* of cotton and woollen, or cotton and silk, or woollen and silk. It is proper also to bear in mind that there are a few other discrepancies in the figures for different years, not explained in the returns from which they are taken. The cotton factories were rather less than half the whole number, but employed more than half the entire number of operatives. The average number of operatives in cotton factories was 120; the average in all factories was 75. Out of the 1932 cotton factories, no less than 1235 were in Lancashire; out of the 1998 woollen and worsted factories, no less than 1298 were in Yorkshire. It will be seen that a remarkable parallelism exists in these numbers; 64 per cent. of all the cotton factories were in Lancashire, and 65 per cent. of all the woollen and worsted factories were in Yorkshire.

The factory legislation since 1844 has comprised five statutes. In 1846 a new Act came into operation, which brought calico-printing works within the range of the inspectors. By the terms of another Act, passed in 1847, the *children* and *young persons* are to work not more than eleven hours a day from July 1, 1847, and not more than ten hours after the 1st of May, 1848. The same provisions were made in relation to women of whatever age; and it thus arose that all women, boys, and girls employed in factories were limited in their hours of working, adult males being alone excepted. Another Act, passed in 1850, introduced a few minor changes, chiefly with a view to prevent night-work in factories. In 1853 an Act was passed making further regulations touching the employment of young children in the evening or night. It was enacted that, after the 1st of September in that year, children should not begin work before six in the morning, or remain at work after six in the evening; in the winter months the hours might be from seven till seven, on due notice being given to the sub-inspectors; work to end on Saturdays at two o'clock. These regulations, subject to exceptions under special circumstances, were to be incorporated with such of the provisions of previous statutes as were not repealed or modified by them. In 1856 an Act was passed to remove doubts concerning the statute of 1844 in reference to mill-gearing; the mill-owners had interpreted this statute in one sense, the inspectors in another; and thereupon the new Act declared that the mill-fencing should only apply to such parts of the machinery as children, young persons, and women are liable to be injured by, either in passing or in their ordinary occupations in the factory. Very violent accusations and recriminations had arisen on this subject, and the statute was intended to settle the question.

It will be seen, on reference to the articles BLEACHING and CALICO-PRINTING, that strenuous efforts have been made to bring bleach-works and dye works under the same regulations as spinning and weaving factories and print works. Much inquiry by commissioners, and much debating in parliament, were bestowed upon this subject in the periods between 1854 and 1857. For a brief statement of the results we refer to the articles above named. There was also, about the year 1857, a strenuous effort made by some of the factory operatives and their advocates in parliament to obtain a "ten hours' bill," but without success.

Having in former paragraphs given a few statistics of factories at various dates since the commencement of factory legislation, we here give a few more relating to 1856, the last year concerning which any very exact enumeration has been made; for, it may be remarked, the half-yearly reports of the inspectors usually advert to current events, and not to total results. The five kinds of factories for textile goods (cotton, woollen, worsted, flax, and silk) were all examined, throughout every part of the United Kingdom, and certain particulars were noted down concerning all. These particulars, and the figures relating to them, we will present in a more condensed form, sufficient for the present purpose:—

	Factories.	Spindles.	Power Looms.	Horse Power.	Males Employed.	Females Employed.	Total Employed.
Cotton . . .	2,210	28,010,217	298,847	97,132	157,186	222,027	379,213
Woollen . .	1,505	1,786,972	14,453	25,901	45,588	33,503	79,091
Worsted . .	525	1,324,549	38,956	14,904	30,023	57,771	87,794
Flax . .	417	1,288,043	7,689	18,322	23,446	56,816	80,262
Silk . . .	460	1,093,799	9,260	5,176	16,899	39,238	56,137
Total	5,117	33,503,580	369,205	161,435	273,137	409,360	682,497

In reference to the several parts of the United Kingdom, without noting any separation of the different textile manufactures, the figures stood thus:—

	Factories.	Spindles.	Power Looms.	Horse Power.	Males Employed.	Females Employed.	Total Employed.
England and Wales .	4,432	30,122,165	339,382	133,092	241,309	330,768	572,077
Scotland . .	530	2,643,049	26,485	19,706	21,279	56,153	77,432
Ireland . .	155	738,366	3,388	8,037	10,549	22,439	32,988

The largest items of course relate to the cotton manufacture in England and Wales. The figures are truly astonishing; 2,050 factories, 26,000,000 spindles, 280,000 power looms, 86,000 horse-power for moving machinery, 14,000 males employed under 13, 134,000 over 13, 10,000 females under 13, and 180,000 over 13. In the interval between 1850 and 1856, the several items, as will be seen on comparison, varied very unequally among themselves. Taking four different years, and three classes of factory operatives, it has been found that the latter have changed somewhat in the relative percentage.

Years.		Males and Females under 13.		Males over 13.		Females over 13.		
1835	..	13	+	37	+	50	=	100
1838	..	6	+	39	+	55	=	100
1850	..	6	+	38	+	56	=	100
1856	..	7	+	36	+	57	=	100

This seems to show that women have increased in number in factories more rapidly than men, boys, or girls.

In the article EMBROIDERY AND SEWING MACHINES, it is mentioned that shirts, collars, and other kinds of ready made linen sold in London, are in a large degree sewn and stitched by machinery. We may here add a few words on this subject in relation to the north of Ireland, where the factory system has been brought into connection with it. The manufacturers of Manchester and Glasgow, and the wholesale dealers of those towns and of the metropolis, have found out that the Irish peasant girls work very neatly with the needle, and are eager to obtain employment on linen, cotton, or muslin work, whether by the ordinary plying of the needle, or by tambouring and sewing machines. Some of the firms now own large establishments in Ireland, where the factory system is in part carried out. In and near Londonderry alone there are more than a dozen factories in which sewing-machines are employed; these machines are at present about 700 in number; and the working of them, with subsidiary operations, employ 1800 women and girls. Taking one with another, these persons (mostly girls) earn about 6*s.* per week each on an average; some, who are quick and clever, occasionally earn as much as 20*s.* In one of the establishments the sewing-machines are driven by steam-power, and are fitted with patent self-acting regulators, still further to increase the automatic action. Besides these machine-sewers working in factories, there are 16,000 hand-sewers scattered over the counties of Londonderry, Donegal, Tyrone, Fermanagh, and Antrim.

We may remark, in conclusion, that in the United States, spinning and weaving factories are much more frequently owned by joint-stock companies than in England. The celebrated cotton factories at Lowell, and numerous others in the northern states of the Union, are held by companies; they are large, well provided with machinery, and worked by operatives who maintain a somewhat higher status than those of England. This may in part result from the more general diffusion of education in that country, a fact of which there seems to be no doubt. In these large American spinning and weaving mills, owned by companies, the proprietors often provide boarding-houses, in which many of the workpeople—especially girls and young women away from their parents' homes—are supplied with food and lodging under a well-organised system, and at prices calculated rather in relation to the well-being of the persons themselves than to the realisation of a profit.

FACULTIES. [UNIVERSITY.]

FAGINE. An alkaloid of unknown composition contained in the beech-nut, *Fagus sylvatica*.

FAGOT, SAP-, a small kind of FASCINE, about 3 feet in length.

FAINTING. [SYNCOPE.]

FAIR, an annual or fixed meeting of buyers and sellers; from the Latin *feria*, a holiday. Fairs in ancient times were chiefly held on holidays.

Anciently, before many flourishing towns were established, and the necessaries or ornaments of life, from the convenience of communication and the increase of provincial civility, could be procured in various places, goods and commodities of every kind were chiefly sold at fairs, to which, as to one universal mart, the people resorted periodically, and supplied most of their wants for the ensuing year. The display of merchandise and the conflux of customers at these the most comprehensive markets for domestic commerce was prodigious, and they were therefore often held on open and extensive plains. Warton, in his 'History of English Poetry,' has given a curious account of that of St. Giles's Hill or Down, near Winchester. It was instituted and given as a kind of revenue to the Bishop of Winchester by William the Conqueror, who by his charter permitted it to continue for three days; but in consequence of new royal grants, Henry III. prolonged its continuance to sixteen days. Its jurisdiction extended seven miles round, and comprehended even Southampton, then a capital trading town; and all merchants who sold wares within that circuit, unless at the fair, forfeited them to the bishop. As late as 1512, as we learn from the Northumberland Household-book, fairs still continued to be the principal marts for purchasing necessaries in large quantities, which are now supplied by the numerous trading towns.

Philip, king of France, complained in very strong terms to Edward II. in 1314 that the merchants of England had desisted from frequenting the fairs in his dominions with their wood and other goods, to the great loss of his subjects, and entreated him to persuade, and, if necessary, to compel them, to frequent the fairs of France as formerly, promising them all possible security and encouragement. (Rym., 'Fœd.,' tom. iii., p. 482.)

When a town or village had suffered from misfortune, by way of assisting to re-establish it, a fair, among other privileges, was sometimes granted. This was the case at Burley, in Rutlandshire, 49th Edw. III. ('Abbrev. Rot. Orig.,' vol. ii., p. 338.)

The Chronicles of Stow and Grafton, published in Queen Elizabeth's time, contain lists of the fairs of England according to the months.

No fair or market can be held but by a grant from the crown, or by prescription supposed to take its rise from some ancient grant, of which no record can be found.

The fairs of Frankfort-on-the-Mayn and Leipzig are still pre-eminent in Europe; each is held three times a year. Leipzig at these times is the mart and exchange of Central Europe, and is visited by merchants and foreigners from the most distant parts of the globe, sometimes to the number of thirty or forty thousand. The whole book-trade of Germany is centred in the Easter fair at Leipzig. Nishnei Novgorod, in Russia, at the confluence of the Oka and the Wolga, has a great annual fair in June, at which an immense number of traders assemble, many of them from the most remote parts of Asia.

FAIRIES, a small sort of imaginary spirits of both sexes in human shape, who are fabled to haunt houses in companies, to reward cleanliness, to dance and revel in meadows in the night-time, and to play a thousand freakish pranks. Both sexes are represented generally as clothed in green, and the traces of their tiny feet are supposed to remain visible on the grass for a long time after their dances: these are still called fairy-rings or circles. They are also fabled to be in the practice of stealing unbaptised infants and leaving their own progeny in their stead. Besides these terrestrial fairies, there was a species who dwelt in the mines, where they were often heard to imitate the actions of the workmen, to whom they were thought to be inclined to do service. In Wales this kind of fairies was called "knockers," and was said to point out the rich veins of silver and lead. Some fairies are fabled to have resided in wells. It was also believed that there was a sort of domestic fairies, called, from their sunburnt complexions, *Brownies*, who were extremely useful, and who performed all sorts of domestic drudgery. The words fairy and browny seem at once to point out their own etymologies.

Bourne, in his 'Antiquitates Vulgares,' supposes the superstition relating to fairies to have been conveyed down to us by tradition from the Lamiæ, or ancient sorceresses; others have deduced them from the lares of the Romans. Dr. Percy tells us, on the assurance of a learned friend in Wales, that the existence of fairies is alluded to by the most ancient British bards, among whom their commonest name was that of the Spirits of the Mountains. The most general conjecture, however, is, that these imaginary people are of Oriental origin, and that the notion of them was first entertained by the Persians and Arabs, whose traditions and stories abound with the adventures of these imaginary beings. The Persians called them *Peris;* the Arabs, *Ginn;* and the Arabs assigned them a peculiar country to inhabit, which they called *Ginnistan*, or Fairy-land.

Shakspere has been singularly happy in his dramatic exhibition of fairies. The belief in these fabled beings has still a fast hold upon the minds of many of our rustics, which may perhaps be considered as a remnant of that credulity which was once almost universal. Poole, in his 'English Parnassus,' has given the names of the fairy court, their clothing, and their diet. Dr. Grey, in his 'Notes on Shakspere,' gives us a description, from other writers, of fairy-land, a fairy entertainment, and fairy hunting; and Dr. King has given a description of Orpheus' fairy entertainment in his 'Orpheus and Eurydice' (edit. 1776, vol. iii., p. 212). Wieland in his 'Oberon' gives an account of the quarrel of Oberon and Titania, with consequences varying considerably from those detailed by Shakspere in his 'Midsummer Night's Dream.' A charm against fairies was *turning the cloak*. The reader who would look further into fairy mythology may consult Percy's 'Reliques of Antient English Poetry;' Sir Walter Scott's 'Essay on the Fairy Superstition,' in the 'Minstrelsy of the Scottish Border;' Keightley's 'Fairy Mythology,' published in 1828, in which the legends of different countries are collected; and Jacob Grimm's 'Deutsche Mythologie,' 1835.

FAITH (*fides*, in Latin), means belief or trust in a fact or doctrine, and is more especially used to express the belief of Christians in the tenets of their religion, and also by figure to mean that religion itself. The great divisions of Christianity, the Roman, the Greek, the Reformed or Calvinist, the Episcopal English, the Independents, and the Protestant or Lutheran churches, have each separate confessions of faith, but they all acknowledge the great fundamental points of the Christian faith or religion, namely, the inspiration of the Scriptures, and the divinity of Jesus Christ. [CONFESSIONS.] In the earlier ages of the Church the chief controversies of theologians, especially in the East, ran upon metaphysical questions concerning the mysteries of the Trinity, the Incarnation, and the divine nature of the Saviour. In modern times controversy has run more frequently upon moral questions concerning the conduct of men, the requisites of salvation, and the discipline of the Church. Faith, the necessity of which is acknowledged by all Christians, has been viewed in various lights with respect to its efficacy. From the earliest ages the Church has taught that faith, or belief in the Redeemer, joined with good works, was necessary for the justification of man; that good works, that is, works acceptable to God, could only be produced by the Spirit of God influencing the heart, but that the human will must co-operate with grace in producing them, though the human will alone is powerless to good unless assisted by divine grace. Still, man being a free agent, the will can call on God, through the merits of the Saviour, for a measure of his grace to assist its own efforts. Thus the co-operation of God and man was held as the means of the justification and salvation of the latter. Luther, however, and Calvin, denied the power of the will to call on God for his grace; they substituted faith, and faith alone, in the merits of the Redeemer, as the means of salvation, by which faith man firmly believes that his sins are at once remitted. But this faith must be sincere, absolute, without a shadow of doubt or distrust; and as man cannot of himself obtain this, it can only be given to him by inspiration of the Spirit of God. Here the question of faith becomes involved with those of grace and predestination. As for our works, both Luther and Calvin look upon them as absolutely worthless for our salvation. Some fanatics, and the Anabaptists among the rest, drew from these premises of the leading reformers some very dangerous consequences, which Luther and Calvin had not anticipated, such as that men might live as profligately as they pleased, and yet, by the inspiration of divine grace, might obtain the faith requisite for their salvation.

The opinions of Luther and Calvin on the subject of faith and predestination have been since considerably modified by many Protestant divines, who have admitted that the will of man must co-operate in order to obtain the grace necessary for justification. The Roman Catholic church admits the merit of good works and repentance, united with faith, for the purpose of salvation. But then, it requires an absolute faith in all the decisions of its general councils in matters of dogma, without the least liberty of investigation on the part of the laity, and without any doubt, for doubt itself is held to be sinful. The Reformed and Protestant churches, generally speaking, hold faith in the fundamental dogmas of Christianity as an essential requisite for salvation.

FAKI'R, an Arabic word, meaning "poor," which is applied to the ascetics of several parts of the eastern world. In this sense it is synonymous with the Persian and Turkish dervish. The word fakir is chiefly used in India. There are fakirs who live in communities like the monks of the western world, and others who live singly as hermits, or wander about exhibiting strange displays of self-penance and mortification. Many of them are considered as hypocrites, and others are fanatics or idiots. [Dervish.]

FALCONRY, or **HAWKING**, the art of training and flying hawks to take other birds. Julius Firmicus, who lived in the middle of the 4th century, is the first Latin writer who speaks of falconers and the art of teaching one species of bird to fly at and catch another. The art, however, had been, in all probability, practised in the East from remote ages, whence it certainly came to Europe.

From the Heptarchy to the time of Charles II. falconry was a principal amusement of our ancestors in England: a person of rank scarcely stirred out without a hawk upon his hand, which, in old illuminations and upon ancient seals, is the criterion of nobility. Harold, afterwards king of England, is thus represented in the Bayeux tapestry, when visiting the court of William, duke of Normandy.

In 'Domesday Book' the practice of falconry is illustrated by numerous entries. In several places we find a sum, no less than ten pounds, made the optional payment instead of finding a hawk ('Domesd.,' tom. i., fol. 134, b. 172, 230); and once, at Worcester (tom. i. 172) a Norway hawk is specified. Aeries, or places destined for the breeding or training of hawks, are entered in the Survey in Buckinghamshire, Gloucestershire, Worcestershire, Herefordshire, Shropshire, and, more frequently than in other counties, in Cheshire, as well as among the lands between the Ribble and the Mersey.

Nor were hawks less prized at subsequent periods. According to Madox ('Hist. Excheq.,' i. 273), in the 14th Hen. II., Walter Cnot, one of the king's tenants, rendered his rent at the exchequer in three hawks and three girfalcons. King John had also his hawks (Pat. 4, Joh. m. 2); and upon the Patent Roll of the 34th Hen. III. a copy occurs of the letter which the king sent in that year to the king of Norway for hawks. In the 34th Edw. III. it was made felony to steal a hawk; to take its eggs, even in a person's own ground, was punishable with imprisonment for a year and a day, besides a fine at the king's pleasure. In Queen Elizabeth's reign the imprisonment was reduced to three months: but the offender was to find security for his good behaviour for seven years, or lie in prison till he did. (Pennant, 'Brit. Zool.,' 8vo, Lond., 1812, vol. i., p. 212.)

By an entry upon the Originalia Rolls of the 35th Edw. III. ('Origin.,' vol. ii., p. 267) it appears that a falcon gentil cost 20*s.*, a tersel gentil 10*s.*, a tersil lest our 6*s.* 8*d.*, and a lanner 6*s.* 8*d.*: these were the prices which the sheriff was to give for hawks for the king's use. In an account-book of the 20th Hen. VIII. a goshawk and two falcons are prized at 3*l.*, and five falcons and a tersil at 8*l.* Bert, in his Address to the Reader, prefixed to his 'Treatise of Hawkes and Hawking,' published in 1619, says he "had for a goshawke and a tarsell a hundred marks."

Falconry was attempted to be revived by George, earl of Orford, who died in 1791; and in Yorkshire, Col. Thornton had a hawking establishment at a rather later period. Sir John Sebright and a few other gentlemen also practised it in Norfolk at the beginning of the present century. As a rural diversion, however, principally in consequence of the enclosures, it has gone into disuse, though there are still occasional attempts made for its revival.

A list of the hawks which were most used by sportsmen in the time of Charles I. is given in Walton's 'Complete Angler;' and an explanation of the words of art in hawking will be found in Latham's 'Falconry,' 4to, Lond., 1633.

The earliest printed treatise on hawking in English is the 'Book of St. Alban's,' fol., 1481, ascribed to Juliana Barnes or Berners, abbess of Sopwell. [Berners, Juliana, in Biog. Div.] There are numerous other and curious treatises upon falconry both in French and English, some of them of very rare occurrence. 'Le Miroir de Phebus, avec l'Art de Fauconnerie,' published at Paris in 8vo, without date, was the first work upon the subject printed in the French language.

FALL OF BODIES. Under this head we propose simply to explain the laws which regulate the fall of a material substance, supposed either to be allowed to drop or to be projected directly upwards or downwards. The motion of a body projected in an oblique or horizontal direction comes under Projectiles, Theory of; the nature of the forces which cause the descent or retard the ascent, under Accelerated Motion, Accelerating Force, Acceleration, Attwood's Machine, Gravity, &c.; and the circumstances which influence more or less the results about to be specified, under Projectiles, Resistance, Motion of the Earth, Motion, Laws of.

The resistance of the air does not greatly affect the motion of bodies, unless either—1, the bodies themselves be very light, as in the case of feathers, or, 2, the velocities be very great, as in that of a cannon ball. The law according to which this resistance acts is not well ascertained for great velocities, but for moderate velocities it is not far from the truth to say that it is as the square of the velocity; that is to say, whatever resistance there may be to a velocity of 10 feet per second, there is *four* times as much to 20 feet per second, *nine* times as much to 30 feet per second, and so on.

Neglecting the resistance of the air, let us first suppose a body (say a bullet) to be allowed to drop from a height above the earth. The law of its motion is as follows. It acquires velocity uniformly at the rate of $32\frac{1}{6}$ feet per second; that is, at the end of a quarter of a second it is in such motion as would, were the action of the earth to cease, cause it to describe $8\frac{1}{24}$ feet in a second. At the end of one second the rate of motion is $32\frac{1}{6}$ feet per second; at the end of two seconds, $64\frac{1}{3}$ per second, and so on; that is, the fall of a body is a uniformly Accelerated Motion. In the article just cited the law of this motion is further explained. We shall here collect the principal formulæ connected with the subject, referring to Pendulum and Attwood's Machine for the manner in which the main fact of the acceleration being $32\frac{1}{6}$ feet per second is proved and verified.

Let $g=32\frac{1}{6}$

$t=$ the number of seconds during which the motion has lasted when the body has attained a velocity of v feet per second, and described a length of s feet.

First, suppose the bullet simply to drop without any initial impulse being communicated. Then

$$v=g\,t, \qquad s=\tfrac{1}{2}g\,t^2=\tfrac{1}{2}v\,t, \qquad v^2=2\,g\,s.$$

Thus, either of the three, v, t, s, being given, the others may be found.

Secondly, suppose the bullet to be projected downwards with a velocity of a feet per second: the consequence is still a uniform addition of g feet per second to the velocity, and we have

$$v=a+g\,t, \qquad s=a\,t+\tfrac{1}{2}g\,t^2, \qquad v^2-a^2=2\,g\,s.$$

Thirdly, suppose the bullet to be projected upwards with a velocity of a feet per second. The action of the earth begins by producing a loss of velocity at the rate of $32\frac{1}{6}$ feet lost per second. This lasts until the velocity of the bullet is entirely destroyed, after which it begins to descend without any initial impulse, and we have the first case repeated.

During the ascent

$$v=a-g\,t, \qquad s=a\,t-\tfrac{1}{2}g\,t^2, \qquad a^2-v^2=2\,g\,s,$$

and the height through which the bullet will ascend is $a^2\div 2\,g$ feet, the time of doing which is $a\div g$ seconds. After this the first case may be repeated; but this is not necessary, for the preceding equations will continue to represent the relations which actually exist, provided that v, becoming negative, be interpreted as indicating that the turn has taken place and the bullet has begun its descent, and also that s becoming negative be interpreted to mean that the descent has continued until the bullet has passed through the point from which it was first thrown, and fallen below it. For instance (supposing $g=32$ for simplicity), let a bullet be projected *upwards* with a velocity of 100 feet per second, where will it be, and at what rate will it be moving, at the end of ten seconds?

$v=100-32\times 10=-220$, or the bullet is moving *downwards* at the rate of 220 feet per second.

$s=100\times 10-\frac{1}{2}\times 32\times 10^2=-600$, or the bullet is 600 feet below the point from which it was thrown upwards.

FALLACY, as defined by Archbishop Whately, is any unsound mode of arguing which appears to carry conviction and to be decisive of the question in hand, when in fairness it is not. Bentham's definition in his 'Book of Fallacies' is this: "By the name of fallacy it is common to designate any argument employed, or topic suggested, for the purpose, or with a probability, of producing the effect of deception—of causing some erroneous opinion to be entertained by any person to whose mind such argument may have been presented." Accordingly if an argument be undesignedly vicious, and without any attempt at deception, it is more correctly termed a paralogism, and it is the intention of fraud that constitutes the fallacy or sophism. There is, however, a legitimate use of fallacy which is too often unnoticed by writers on logic. Thus, in modern times Kant has employed the dilemma for a purely scientific purpose; and from the impossibility of two opposite and conflicting cases, has inferred, not as is the usual deduction, that the hypothesis upon which they both rest is false and untenable, but that the truth is intermediate. In like manner did Zeno of Elea infer the inadequacy of sense to represent the truth, from his conclusion that either a bushel of corn must make no noise in falling, or else the fall of the smallest portion of a single grain must be perceptible to the ear. Again, the famous 'Megarian fallacies of the Heap and the Bald head' (acervus calvus), in which it is proved that these notions are incapable of any precise determination, may have been designed to show that the distinctions of degree (here represented by Heap and Bald head) are unavailable for philosophical purposes, and thereby to call attention to the difficulty of admitting into science the vague representations of sense.

Aristotle, in his treatise 'De Sophisticis Elenchis,' has laboured to expose and classify the different fallacies which he terms *sophismata* (σοφίσματα). He divides them into those *extra dictionem* (ἔξω τῆς λέξεως), where the fallacy is in the process of reasoning, and those *in dictione* (παρὰ τὴν λέξιν) where it lies in the subject-matter. The former have by the schoolmen been called formal, the latter material. Dr. Whately proposes the terms logical and non logical; which terminology has at least the advantage in a scientific point of view that it excludes from the domain of logic much that is extraneous to it; for the fallacies of form may be reduced to the syllogism with four terms which the analytical process of demonstration can alone discover, whereas those of the matter must be corrected by the formation of valid principles and a correct generalisation of terms, which belong to the synthesis of induction, which is totally alien from logic as the science of demonstrative reasoning.

For an enumeration and exposition of the several sophisms, see the sections on fallacy in Whately's 'Logic;' and for the exposure of that class of fallacies which he has called political fallacies, the work of Bentham, already cited.

FALLING STARS. [AEROLITES.]

FALLOW operations are those acts of cultivation which depend for their fertilising influence rather on the mere tillage of the soil, its disintegration, disturbance, and exposure to external agencies, than on the direct addition of fertilising matter. Originally the term *fallow* applied to that portion of land in which no seed is sown for a whole year, in order that the soil may be left exposed to the influence of the atmosphere, the weeds destroyed by repeated ploughings and harrowings, and the fertility improved at a less expense of manure than it would be if a crop had been raised upon it. Even then a large portion of the benefit derived from fallow was attributed to the mere tillage operations included in the term; but, in addition to this, manuring was (and indeed still is) an almost invariable part of a summer fallow. A bare summer fallow is, however, now comparatively rare, and fallow crops, those which allow of fallow operations during their growth, are the fertilising agents substituted in its place.

The practice of fallowing land is as old as the Roman Empire. It appears that wherever the Romans extended their conquests and planted colonies, they introduced this mode of restoring land to a certain degree of fertility when exhausted by bearing grain. The principle on which it was recommended was, however, erroneous. It was thought that the land grew tired of raising vegetable produce and required rest, and hence this rest was often all that constituted the fallow; the tillage, which alone is the improving part of the process, being almost entirely neglected. Where land was abundant and the population thin, it was no great loss to allow a considerable portion of the soil to remain unproductive; and it was cheaper to let land lie fallow during the course of a whole year, which gave ample leisure for every operation, than to accelerate the tillage and increase the manure put upon it. But when land becomes of greater value with the increase of population, it is a serious loss if a great portion of the soil be thus left in an unproductive state. Accordingly the attention of agriculturists has been turned to lessen the necessity of fallows, and to substitute some other means of restoring fertility. It is acknowledged by all experienced farmers that manure alone is not sufficient for this purpose. The ground must be tilled and noxious weeds destroyed; and the only efficacious mode of doing so is to stir the ground at the time when their seeds have vegetated, their roots have made shoots, and before any new seed can ripen. But this is exactly the time when corn is usually growing, and when the land cannot be stirred to expose it to the heat of the sun and to dry the roots which are turned up. The only apparent remedy is therefore not to sow it during one summer, and on this principle lands are usually fallowed. The manner in which this is done has been noticed before [ARABLE LAND]; and the common process is so simple, that, provided the purpose of fallowing be kept in view, the operations require only a little attention to time and weather to be performed aright.

There is no difference of opinion respecting the manner of extirpating weeds by repeated ploughing and harrowing, but there is with respect to the influence of the heat of the sun upon the land. Some men are of opinion that light is the great purifier of the soil; that it decomposes certain noxious particles, which are the result of the formation of the seed, and which have been termed the excrements of plants. Physiologists agree that the roots draw the nutritive juices out of the soil, that they undergo a chemical change in the plant, and that there is an exudation also from the roots, which may be looked upon as the residuum of the natural process. De Candolle, Raspail, and other eminent physiologists have placed this point beyond controversy; but no one has yet been able to collect these matters so as to analyse and compare them; and the reasonings on the subject have been merely conjectural. In particular soils and situations a scorching sun has a pernicious effect on the soil which is exposed to his rays; and where it is shaded by a crop which covers it completely, it seems to have acquired fertility, which the exposed surface has not. But this is not sufficient to establish a general rule. Some soils which are of a wet nature are greatly improved by being as it were baked in a hot sun. Not only are the weeds destroyed by the abstraction of moisture, but the soil thus becomes lighter and more friable. On sandy soils the reverse is the case, and on intermediate loams the effect will be more or less advantageous as they approach nearer to the clay or to the sand. In light sandy soils, then, it is probable that the only advantage of a naked fallow is to kill weeds, especially the couch-grass (*Triticum repens*), which is apt to infest light soils: and that the exposure to the sun in hot weather is not only no advantage, but probably detrimental. If, then, any means can be devised of clearing light lands from weeds without leaving them fallow for a whole summer, a great advantage will be obtained. This has been effected completely by the cultivation of turnips and clover, which was first practised in the light soils of Flanders, and afterwards introduced into the similar soils of Norfolk, from whence it has spread all over Great Britain, and is beginning to be adopted more generally in Ireland. The advantage of the turnip culture is so great in light lands, that it has gradually been extended through the different gradations of loams, till it has reached even the colder and stiffer clays, on which it would at one time have been thought absurd to attempt to raise this root. But this has been attended with an important benefit. It has made the cultivators of heavy soils turn their attention to the drying of their lands, by draining, and to improving their texture by burning and by deep tillage, in order to make them capable of bearing turnips; and although the extended culture of this useful root is not what we should recommend for cold wet clays, we highly approve of all improvements which will make such lands capable of bearing good crops of turnips. Unless the turnips can be consumed by sheep on the spot, or by cattle near at hand, without injuring the land in taking off the turnips and carting on the manure, there will be no great advantage in a crop of turnips; and some other substitute must be found for the occasional fallow before it can be altogether abandoned. The great hope of the clay-land farmer, as to the possibility of the successful cultivation of a fallow crop on such land, rests on the mangold-wurzel and the cabbage crop [CABBAGE; MANGOLD, *Cultivation of*], which are especially fitted for soils of the stiffer class. On light lands the preparation for the turnips, the abundant manuring, and subsequent hoeing, are as effectual in cleaning the land and bringing it into a fertile state as any complete fallow could ever be; and the clover smothers and destroys the seed weeds which may have come up amongst the barley or oats sown after the turnips. There are several ways in which the cultivation of light soils may be varied without adhering strictly to the Norfolk rotation, so as to introduce a greater variety of produce. Tares may be sown on the better sorts of light lands after a good tillage given immediately after harvest. If they are fed off or cut green in May and June, early turnips may be sown after them, which will be fit to feed off or draw for the cows in September, in good time for ploughing up the land for wheat-sowing. In this case the land gets all the ploughing necessary to clean it completely, and exactly at the best time. Three ploughings may be given after the tares if the land is not clean, and the turnips being well hand-hoed and horse-hoed, the land will be perfectly clean to receive the wheat-seed. Manure may be put on for the tares or the turnips; and if these are fed off with sheep, they will so enrich the soil, that the next crop cannot fail to be abundant. As a general rule, however, tares are better adapted for the clay soils; and rye is a better crop to take before turnips on sandy loam. By varying the management of light land according to circumstances, and with some judgment, many more profitable crops can be raised than by the common simple rotation, in which a fourth of the land is sown with turnips. If this crop fails, which is often the case where it recurs so often, the whole system is deranged, and the loss is very great. The introduction of a greater variety of produce in the cultivation of light lands, in imitation of the Flemish practice, and the increase of stock kept in consequence, would be an important step in the improvement of British husbandry.

On heavy soils it is often impossible to keep the land clear of weeds, in wet climates and unfavourable seasons, without a complete fallow, and when this is the case it is best to do the thing effectually. Upon cold wet soils, which should always first of all be well under-drained, no pains should be spared to get the land perfectly clean: if both climate and circumstances interfere with the thorough cultivation of a fallow crop, then let the soil be exposed to the frost of two winters and the heat of one summer and part of another, as already mentioned [ARABLE LAND.] Only one crop is lost by this method, and if the land is properly worked, cleaned, and manured in autumn, it may be sown with barley or oats in the spring of the second year. The crop will be ample, and the subsequent produce of clover equally so, and the land so clean, that, with proper manuring, several crops may succeed, such as wheat, beans, oats, tares, wheat, without the necessity of another intervening fallow. The advice we would impress on the minds of the cultivators is—Avoid fallows if you can keep your land clean; but when you fallow, do it effectually, and improve the soil at the same time by chalk, lime, or marl, according to circumstances. Do not spare either ploughs or harrows in dry weather. If you dare not trust to the drainage which the land has received, then lay the stitches high and dry before winter, and deepen the water furrows well with the spade. By following these rules the stiffest land may be brought into a good state of cultivation; and the farmer will not find, by the growth of weeds, docks, and thistles, that his labour and manure are thrown away, as is too often the case. Experience has fully proved that the air and the dews impart fertility to the soil, and that land which has been well fallowed and stirred requires less manure than it would otherwise do. Fallowing alone will not make up for want of manure, nor will manuring be sufficient without ploughing and cleaning the land properly, and exposing it to the influence of the atmosphere, especially in autumn and in spring; but a great saving of the one and the other may be effected, by judiciously varying the crops so as to admit of ploughing the land at different seasons of the year.

It is asserted by some old fashioned farmers that the plough alone is sufficient for all the purposes of fallowing. This is a great error, which leads to useless and unnecessary labour. We would almost say that ploughing the fallows is never necessary, except to enable the drags and harrows to stir the land. The first ploughing of the stubble cannot be too shallow, and the harrows should be set to work before the wet weather sets in. When the surface is become mellow and clean, the land may be ploughed deep, and the soil below should be brought up and exposed to the air and frost all the winter. In spring the drag should begin the work again before the soil is hard. It may then be ploughed in narrow ridges right across the old stitches, or obliquely, and left for the influence of summer. The drags will level all these ridges when the manure is to be put on; and this being ploughed, the land is fit to receive the seed, if wheat is the crop intended. If it is left for barley, it must have another ploughing in spring, and be well harrowed before the seed is sown, especially if this is done by the drilling-machine. The clover or grass-seeds may be sown immediately after, and the land lightly rolled. There is no danger of making it too fine in spring. Without a fine tilth no good barley can be expected.

No account of fallow operations would be complete without a reference to the Lois-Weedon system of cultivation, in which the Rev. S. Smith, incumbent of that parish, has improved upon the system of Jethro Tull, and been enabled to grow excellent successive crops of wheat in the same field for more than a dozen years. It is by far the most notable illustration of the fertilising influence of mere fallow operations which this country exhibits, and it is a remarkable thing that a practice of such proved profitableness does not more rapidly extend. The following remarks descriptive of it are taken from the 'Agricultural Gazette.'

"The Rev. Samuel Smith has now had thirteen successive crops of wheat off the same field; the last was 38 bushels, the previous one was 40, the one before was 36, the one before that was 37, 'and of prior years, beginning with 1847, the average yield may be safely given at 34.' It is not that the land is particularly fertile; it 'is really nothing but the ordinary heavy wheat land of the oolitic formation. Thousands and ten thousands of acres of the same quality extend across the country from the coast of Dorset to the Humber; and the rent of such land is under 30*s.*, being lower by 20*s.* at least than the red land of the county.' These results have not been kept a secret: they have been published far and wide—first, when agriculture was in difficulties, as 'A Word in Season,'* for such it surely was when we were all desponding over the gloomy prospect of wheat at less than 10*l.* a load; and it told us how 34 bushels of wheat could be grown perpetually on every acre of wheat land for less than 7*l.*, 2*l.* of which were rent. And these results have been published and republished, now a sixteenth time, still as a 'Word in Season,' for such it will continue to be, not only when farm profits are difficult, but so long as they are desirable. Lois-Weedon practice and experience are very generally known. Is the account of them incredible? Those who only know of them by hearsay or mere rumour may perhaps plead unbelief. Hardly any one, however, who has read the tract describing them can do so—a simpler, clearer, more straightforward statement never yet was written in the English language; and no one who knows either the locality or the author can doubt it for a moment. It is perfectly true that for the last eleven years nearly 35 bushels per acre have been annually grown upon the same land without manure, at an average annual cost, including rent and taxes (2*l.* 4*s.* 3*d.*), of 7*l.* 3*s.* 9*d.* The Lois-Weedon mode of growing wheat consists essentially in the deep cultivation (during the growth of the crop) of wide fallowed intervals between adjacent triplet rows—which intervals are the seed-bed of next year's produce. As you walk *across* the field you traverse alternate strips of plant and fallow—three rows a foot apart and then a yard-wide blank. These blanks being deeply and diligently cultivated during the autumn, winter, spring, and even summer, while the plant is sprouting, growing, and even maturing, are at once the feeding ground of the growing crop, and the store-house of food for the triplet rows of plants which next year they are to bear. These triplet rows thus yield a good average crop per acre annually and perpetually on what is really the moiety of the acre where they grow. That is the fact. Why is it not more generally acted on? It is not incredible. These fallow intervals, though unmanured directly by the hand of man, are indirectly abundantly supplied with the food the wheat-plant needs. Both ammoniacal manures and mineral manures are added in abundance. That the fertility of the soil is unimpaired is proved by the increasing crops it yields. The deep and frequent tillage brings the matter of the subsoil and the soil more thoroughly under the action of the rain water and the air, and the silicates, and phosphates, and alkalies, of which the store is practically inexhaustible, are made ready in abundance for the use of the growing plant. The porous and friable condition of the land, too, under this treatment is just such as enables the absorption and retention of the largest quantity of the ammonia of the air, and this accordingly is also furnished in abundance to the growing plant, as well as stored up for the next year's crop. There is thus nothing in the experience, when considered along with the practice, rendering it inherently improbable; or requiring us to look with more than ordinary care for the mistake which has been made. We cannot but believe that an experience at once so consistent and so remarkable will ultimately be more generally copied."

FALSE IMPRISONMENT is an unlawful arresting or imprisoning, either without just cause, or without proper legal process. In whatever manner the unlawful detention arises, it is false imprisonment, for which an action for damages lies.

When erroneous process issues out of a court having jurisdiction in the matter, a bailiff or officer who arrests a party in execution of it may excuse himself in an action for false imprisonment by showing that the court had jurisdiction; but if the court out of which the process issues has no proper cognisance of the cause, then, as the whole proceedings are *coram non judice*, the officer will be liable.

If an arrest be made by one who is not a legal officer, or who has not at the time a warrant, or is not named in it, it is a false imprisonment, for which an action lies. If a sheriff or his bailiff arrest a man out of his county, or upon a warrant of a justice whose commission has expired, or arrests the wrong party, he is liable.

Mere irregularities in lawful process may constitute false imprisonment; but in such cases the judges will discharge the party upon condition of his waiving his right of action.

All persons concerned in a wrongful imprisonment are liable in an action of false imprisonment, and the party aggrieved may sue any one of them. Thus, if the plaintiff in a suit brings an unlawful warrant to the sheriff, or if he bring a good warrant but direct the sheriff to the wrong man, the action will lie against both.

Sheriffs and their officers, high bailiffs of the county courts, constables, and other peace officers, are however protected from the consequences of a mistake by a great variety of statutes.

FALSE POSITION, a rule of arithmetic, which, though originally applied to such questions as are soluble by equations of the first degree, has been in modern writings, and upon principles explained in APPROXIMATION and INTERPOLATION applied to equations of all degrees. It is however of very little use, though of some notoriety, and a general explanation will be sufficient.

Let there be a function of x, ϕx, which it is desired to make equal to a, and firstly, let this function be such that successive *equal* increments added to the value of x produce successive *equal* increments (or decrements) in the value of ϕx (which is, in fact, supposing that ϕx is of the form $mx + n$): assume two values for x, say p and q, and let the corresponding values of ϕx be P and Q. If then (to use the easiest form of speech) a uniform increase of x is accompanied by a uniform increase of ϕx, and if x represent the value which makes ϕx equal to a, it follows that the interval between P and Q bears to that between p and q the same proportion as the interval between P and a bears to that between p and x. Or x can be obtained from the proportion

$$P - Q : p - q :: P - a : p - x.$$

If the preceding be not easily understood, the same proportion may be immediately deduced from

$$mp + n = P,\ mq + n = Q,\ mx + n = a$$

which follow from the several hypotheses made.

When ϕx and x do not increase uniformly together, it is nevertheless true that they do so *nearly* when the successive increments added to x are very small. If then p and q can be found so that P and Q are near to a, the use of the preceding proportion will produce a value of x which is nearer the truth than either p or q, and may be substituted for either in a repetition of the process, which will then produce a still nearer value.

The rule of False Position, as thus extended, is simply Brigge's and Newton's well-known method of approximating to the roots of equations, with this difference, that instead of the differential coefficient of ϕx, the approximation $(P - Q) \div (p - q)$ is used. The equation of the first degree is one in which either method will bring an accurate result in one process; but the notoriety of the rule of False Position arose out of its appearing that a couple of errors, or wrong solutions, were made infallibly to give the right result; and thus it is that Recorde says he can solve mathematical questions by taking the answers of any children or idiots who may be in the room. To persons ignorant of algebra there seems to be a mystery in the being able to make any two guesses, however remote, to discover the truth. Thus, what is that number whose half, third, and fourth, together with 10, make 62? Make any guess, say 12: the half, third, and fourth of 12, together with 10, make 23, which is wrong. Make another guess, say 60, which produces 75, also wrong. The difference of the wrong results, 75 − 23 or 52, bears to the difference of the wrong assumptions, 60 − 12, or 48, the same proportion as the excess of the result 75 over 62 (the required result) bears to the excess of 60 over the truth. But 52 : : 48 : 13 : 12, or 12 is the excess of 60 over the truth, that is, the true answer is 48, as may easily be verified.

When the equation is of the form $mx = a$, one guess only will suffice. If the assumption of p give P, or if $mp = P$, then $P : p :: a : x$.

FALSETTO, in Music, an Italian term, signifying a false or artificial voice, produced by tightening the ligaments of the glottis, and thus the vocal compass is extended about an octave higher. The Italians call the falsetto *voce di testa*, or voice from the head; the natural voice *voce di petto*, or voice from the chest.

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* 'A Word in Season, or How to Grow Wheat with Profit.' By the author of 'Lois-Weedon Husbandry.' Sixteenth edition. J. Ridgway, Piccadilly.

FAN, an instrument or machine for agitating the air by the wafting or revolving motion of a broad surface, for the purpose of producing artificial currents. Large revolving fans, driven by machinery, are frequently used either to facilitate the cooling of fluids or the process of winnowing, or as blowing-machines to urge the combustion of a fire, or to assist in ventilation. Another application of such an apparatus is for the purpose of regulating or checking, by the resistance of the air to its rapid motion, the velocity of light machinery. A familiar example of such a use is afforded by the revolving fans of a musical snuff-box.

In its more ordinary acceptation the name fan is limited to the well known instrument employed by ladies for producing refreshing coolness, the use of which, under the names *flabellum* or *flabellulum* in Latin, or *ῥιπὶς* or *ῥιπιστὴρ* (diminutive, *ῥιπίδιον*) in Greek, was well known to the ancients, whose fans, however, according to the article 'Flabellum' in the 'Dictionary of Greek and Roman Antiquities,' edited by Dr. Smith, were not, like most of those now used, 'so constructed that they might be furled, unfurled, and fluttered, nor were they even carried by the ladies themselves,' so that, as the writer of that article observes, the various manœuvres so wittily described in the 102nd number of the 'Spectator' as the 'exercise of the fan' were wholly unknown to the ancients. From the numerous references given in the article above referred to, it would appear that while ancient fans were often of elegant forms, of delicate colours, and of costly and splendid materials, such as peacocks' feathers, they were stiff and of a fixed shape. Some were made of separate feathers joined at the base, and further united by a thread passing along their tips, and another tied to the middle of the shaft of each feather, and such were in use in England during the reign of Elizabeth; others appear to have been made by fastening together, back to back, the two wings of a bird, and attaching a handle at their base; while others again were formed of linen stretched upon a light frame. They were usually held by female slaves, beautiful boys, or eunuchs, whose duty it was to wave them so as to produce a cooling breeze; and the employment of such attendants was not confined to ladies, for we read in Suetonius that the Emperor Augustus had a slave to fan him while asleep. Fans of a softer kind, to which the name of *muscarium* or *μυιοσόβη* was applied, were used for driving off flies from living persons, from articles of food, and from things offered in sacrifice; and another kind of fan was employed for urging the combustion of a fire, a practice which, to conclude our quotations from the source already indicated, 'gave origin among classical writers to expressions corresponding to ours, meaning to fan the flame of hope, of love, or of sedition.'

Fans are much used in China, India, and other Eastern countries, and those of the Chinese are made to fold up in the same way as those commonly used by European ladies. Among this people fans are used by both sexes, a fan enclosed in a worked silk sheath being one of their frequent accoutrements. These are of either paper or silk, but with the Chinese, as well as the Europeans, fans are sometimes made of elegantly carved or perforated slips of ivory. Whatever be the materials employed, much skill is often displayed in the decoration of fans, and in some cases artistic talent of a high order has been applied in painting them. The mode in which they are constructed to open or fold together at pleasure is too well known to need description.

FAN MANUFACTURE. The manufacture of ladies' fans is a larger department of industry than would be generally supposed. After a considerable interval, during which fans were little used, they came again into favour a few years ago; and the manufacture is conducted in France on a large scale. The firm of M. Duvelleroy at Paris, manufactures fans for the courts not only of European countries, but for those even of Africa and Asia, amounting in some instances to the value of 1000*l.* each.

M. Duvelleroy employs many hundred persons. He has made it a point to grasp the two extremes of the scale in costliness as well as all intermediate degrees; for he makes fans from one halfpenny each to one thousand guineas. Every halfpenny fan goes through no less than fifteen hands: a proof that the factory system must be thoroughly carried out in that establishment. Duvelleroy's fans are sent to all parts of the world, and are now competing in the East with those of China. Spain is trying to maintain a home manufacture, but all the best specimens come from Paris. America affords the best markets, for while the ladies of North America closely imitate the fashions of Paris, those of South and tropical America are passionately fond of gorgeous fans, on which exciting scenes are painted in dazzling colours. Duvelleroy has a large corps of artists, who study the peculiar tastes of every nation in their pictures and colours.

In the manufacture of fans, the chief parts are called the *handle*, the *brins*, the *panaches*, the *end*, and the *leaf*. The *handle* is the part at which all the rest of the fan is hinged together, and which is made of ivory, wood, or any hard material. The *brins*, or radiants, from twelve to twenty-four in number, radiate from the handle; they are about four inches long. The *ends* are elastic pieces which connect the brins with the handle, and which form with them the skeleton of the fan; they are made of mother-o'-pearl, tortoise-shell, ivory, horn, ebony, bone, citron-wood, sandal-wood, or plain wood, and are rivetted with diamonds, gold, pearls, or more cheap material, according to the price. The *panaches* are the two outermost brins, made wider and stronger than the rest for security. The *leaf* is the surface of the fan, cut into the form of the segment of a circle. It is made of paper, of cabretille (very delicate kid-skin), vellum, parchment, satin, tulle, gauze, or crêpe, according to circumstances. There are as many folds or plaits given to this leaf as there are brins; and the brins govern the opening and closing of the leaf.

It is in the painting and decorating of the leaf that the costliness of the best fans chiefly consists. Duvelleroy has a number of highly paid and accomplished artists engaged in this department. The fans sent by that firm to the Great Exhibitions in London in 1851, and Paris in 1855, excited great attention.

FANARIOTES, a name formerly applied to the inhabitants of the Fanar or Greek quarter of Constantinople. After the capture of Constantinople by the Turks, the Greeks of the Fanar, taking advantage of the ignorance of the Turks, succeeded in rendering themselves necessary to the ministers of the Porte as translators, and to other Turkish grandees as secretaries, agents, and men of business in general. They were all comprised under the general denomination of Grammatikoi, clerks or scribes. At first they were not distinguished from common servants; and the office of the translator to the Sublime Porte conferred no consideration on the individual who held it. The Greek translator explained to the Turkish ministers the contents of a foreign despatch, after which he retired into the great hall of the palace, where he waited with other menials till his masters might want him.

In the year 1669 a Fanariot, named Panayotaki, was first appointed official dragoman, and subsequently all the dragomen were taken from their class. The Fanariotes being thus the only agents of communication betwixt the Porte and the European governments, necessarily acquired a great influence over the Turkish government, and they took good care to turn it to their own advantage. In the beginning of the 18th century the Fanariotes succeeded by their intrigues in prevailing on the Turkish government to choose from among them the Hospodars or princes of Moldavia and Wallachia, which dignities had been hitherto bestowed on natives of the above-mentioned provinces.

Mavrocordato was the first Greek who was nominated Hospodar of Wallachia in 1711. A crowd of Fanariotes always followed the new Hospodars, who employed them in different offices in their respective provinces, where they became notorious for their unprincipled exactions, employing every means, however odious, to acquire as much wealth as possible during their short and precarious tenure of office. The Hospodars, who partook of this ill-gotten wealth, countenanced and protected them in all their proceedings. The mode of government has been since changed in the above-mentioned provinces.

These were not the only sources of wealth to the Fanariote families: the bankers of the Fanar disposed of the greater part of the military and civil appointments in the Ottoman empire, through corrupt influences. An interesting picture of the Fanariotes is given in Mr. Hope's celebrated novel 'Anastasius; or, the Memoirs of a Greek;' as well as in the 'Essai sur les Fanariotes,' by Marco Zallony; and in Von Hammer's 'Constantinople and the Bosphorus.'

The events which have followed the last Greek revolution, and the subsequent events in the Turkish empire have almost entirely annihilated the Fanariotes as a class, though some Greek families are still distinguished by the name.

FANCY, a corruption of phantasy (*φαντασία*), which term in ancient philosophy indicated the sensuous appearance of an object, and in a general sense was used as co-extensive with conception, or the faculty by which man reproduces images of objects either absent or present, without an immediate impression on the organs of sensation. In later times its signification has been greatly narrowed, and it is now limited to a particular province of the imagination, with which, however, it is often frequently confounded in loose and inaccurate language, and to which it is employed as equivalent. Imagination differs from conception either by the greater distinctness and vividness of its images, or else by combining the manifold materials of experience into a new and true unity. In the former case it is merely reproductive; in the latter creative, and becomes fancy :—

> "Of all external things
> Which the five watchful senses represent
> She forms imaginations, aerie shapes."
> MILTON, *Par. Lost*, v.

Fancy is a higher energy of the mental activity than imagination simply, but is nevertheless dependent upon it, since it is the imagination that furnishes the materials out of which it creates its phantasies either by modifying or exaggerating them, or by forming new combinations, and by a prosopopœia investing its personification with the properties of real beings. Imagination is necessary to authors generally, but both imagination and fancy to the poet; the latter presenting him with those lofty speculations which comprise what has been termed the ideal of art, and furnishing the link for that enchainment of his ideas which, rejecting the restraint of all general laws, is wholly dependent upon the peculiarities of the poet's mental temperament.

FANDANGO, a quick dance in $\frac{3}{8}$ or $\frac{6}{8}$ time, much admired and practised in Spain, and supposed to be of Moorish origin; though Volney ascribes a far higher antiquity to it, believing it to have come originally from Carthage, and thence by way of Rome into Spain. The probability however is that it was brought into Europe by the Arabians, to whom certainly it may have been transmitted from remote ages. Like many other dances, this is performed with more or less propriety according to the degree of delicacy possessed by those who practise it.

FARM. A farm is a portion of land which is set apart for cultivation either by the proprietor or by a tenant who pays a certain stipulated rent for it. We shall consider it in this latter sense; and, without entering into the mode of cultivation, we shall notice the circumstances which determine the profit that a tenant may reasonably expect to make in return for his trouble and outlay.

The first thing to be considered in taking a farm is the capital which the tenant is possessed of, or of which he can procure the use at a reasonable rate. If a man takes a farm without the means of stocking it properly, and is restrained in his first outlay, he will never be able to cultivate it with benefit to himself or to his landlord: he will be obliged to sell his produce at a loss, to over-work his cattle, and to keep a smaller quantity of stock, and consequently make less manure than is required to keep the farm in a productive state. It is not sufficient that he has the means of stocking the farm; he must have wherewith to pay the greater part of the whole expenses and the rent for the first year. In the present state of agriculture, a man who takes a farm of 200 acres of arable land, or land partly arable and partly good pasture, will require from 1600*l*. to 2000*l*.; and it is not the interest, either of the landlord or the tenant, that he should take the farm unless he can command that sum. The amount of capital required depends to some extent on the quality of the land; very rich land may require less capital in proportion to the rent than poor land, especially if the poor land requires draining, chalking, or marling, before it will produce any tolerable crops. Nevertheless, the capital required may under certain styles of cultivation be in proportion to its fertility, for when grazing is the rule, the stock needed will be in proportion to the quantity of food to be consumed. All these circumstances must be taken into consideration before a farm is hired.

When it is ascertained what extent of farm may be safely undertaken with a given capital, the most important object to be attended to is the condition and fertility of the soil, not only with respect to the natural quality of the land, but the actual state it is left in by the preceding system of cultivation. A moderately fertile soil, in good condition, will give a greater profit for several years than a better soil which is partially exhausted and rendered foul by injudicious management and over-cropping. For this purpose it is necessary to ascertain what has been the state of the crops for several years before, how the land has been ploughed, and whether the crops have been heavy with or without manure. There is no method yet found out of fully ascertaining the comparative value of land which has been exhausted. It would be a question well worth the investigation of modern chemists, who have made such progress lately in the analysis of vegetable substances, and would be invaluable to farmers and proprietors of land. In the mean time the nature of the weeds which abound on the land will give some clue to its state; and an experienced person will collect from various minute appearances in the soil whether it has been fairly managed or exhausted. It is in general more advantageous to take a farm in a district with which you are well acquainted. It will be a great advantage if you have had an opportunity of seeing the land at all times, observing it in different seasons and states of the weather, and especially of seeing the crops threshed out, and ascertaining the quantity of corn which is usually yielded from a certain quantity of straw, for lands very similar in outward appearance will produce a very different return when the crops are threshed out. A want of attention to these circumstances is the cause that a man who comes from a distant part of the country and hires a farm on his own judgment seldom succeeds so well as might be expected, even with a superior knowledge of agriculture. He naturally compares the soil with some similar soil which he has been acquainted with. If he comes from a district where the soil is sandy, and where clay is in request, he will give the preference to very stiff loams; if he comes from a cold wet clay, he will prefer the sands; and the chances are, that he is mistaken in his judgment, and finds it out when he has already embarked his capital in a losing concern.

Next to the nature of the soil is to be considered the convenient situation of the farm, the disposition of the fields, and the adaptation of the farm buildings to the most profitable occupation of the land. The roads, especially those which lead to neighbouring towns, whence manure may be obtained, are a most important object; and if there is water-carriage, it greatly enhances the value of the farm. The roads to the fields, and the distance of these from the farm yard; the convenience of having good pasture, or land easily laid down to grass, near the homestead, and especially the situation of the farm-buildings with respect to the land, and the abundance of good water, are all circumstances which must be well considered, and which will greatly influence the probable profits, and consequently the rent which may be fairly offered. A central situation is no doubt the most advantageous for the farm-buildings, as greatly diminishing the labour in harvest and in carrying out manure. But there may be circumstances which render some spot nearer the extremity of the land more eligible, and it is only when entirely new buildings are to be erected that there is a choice. The old farm-buildings are generally in low and sheltered situations, but it is a great inconvenience to have to carry the manure, which is the heaviest thing carted on a farm, up a steep hill. The best situation is on a moderate slope, neither in the lowest nor highest ground.

The disposition of the buildings is of great importance both to the landlord and tenant. Large straggling buildings are inconvenient, and cost much in repairs. The house should be neat and comfortable, fit for the residence of a farmer who has a capital such as the farm requires. The rooms should be airy and healthy, facing the south, with a neat garden in front of the house. When the farmery is connected with the farm-house, there should be near the latter and the farm-yard a small paved court separated from the yard by a low wall. In this court, which should communicate with the dairy, the utensils may be placed on proper benches to air and dry in the sun. The architecture of the buildings may be left to the taste of the proprietor or his architect. The simpler it is, the more appropriate. The plan of having large yards as the main feature of the arrangement—these yards to be surrounded by the necessary buildings—is a bad one, but where it prevails they should be sheltered on the north side by the barns, which need not be so extensive as used formerly to be thought necessary. There must be a threshing machine; and a single floor to thresh the seeds upon, and to employ the men occasionally in winter, is quite sufficient. Every farm which is so extensive as to require more than one floor to thresh the corn on ought always to have a threshing-mill attached to it. [HOMESTEAD.]

Yards with sheds for the cattle to shelter themselves under in wet and stormy weather, are a great advantage, and may be added at a trifling expense to any set of farm-buildings.

For a small occupation, where the tenant is but a little above the rank of a day labourer, a set of buildings all under one roof, and forming the longer side of a yard, which may have open sheds round it, is at once convenient and economical. If this building is thought too long, it can very easily be divided into two, which may be placed at right angles to each other and form two sides (N. and E.) of a square. The farm-house and cow-house might form one side, and the stables and barns the other. This is the more common distribution in Flanders.

For a fuller reference to the subject of farm-buildings, we must refer the reader to the article HOMESTEAD. A principal thing to be attended to is to have plenty of room for cattle; and where old barns remain much larger than is required according to the present mode of stacking corn in the yard, they can be very advantageously converted into cow-stalls or ox-stables. Where many sheep are kept, it is of great advantage to have a sheep-yard, with low sheds all round, at the time when the ewes lamb, especially when the season is wet and chilly, which hurts them more than a dry frost.

In valuing the rent of a farm the habitation of the farmer is seldom taken into account, and it ought not to be above the station of the tenant; but the buildings immediately connected with the cultivation necessarily add to the rent or diminish it, as they add to or diminish the profit.

The next important question is what may be a fair rent both to the landlord and the tenant. This depends as much on the mode of cultivation adopted as on the fertility of the soil. The tenant must have a fair interest for his capital, and a fair remuneration for his trouble. In the old system a third of the gross average produce was considered as a fair rent, including all the direct payments for the occupation of the land, such as tithes, rates, and taxes; another third was supposed to cover the labour and expenses of the farm and interest of capital; and the remaining third was appropriated to the maintenance of the farmer and his family, out of which he had to save whatever he laid by as a clear profit. But this calculation is no longer applicable to the present state of agriculture. The expenses are greatly increased, and the produce is also greater. It requires a greater capital, and more skill to manage a large farm. The tenant is a man of more liberal education, and his habits are more expensive. The occupier of 500 acres of land in England expects to live as well as a land-owner of 500*l.* a year income. He cultivates better by applying more labour, and much of the produce is owing to his skill and his capital. He therefore expects a greater share of the produce than the landlord, not only to repay his outlay, which is greater, but to live upon.

In Scotland, it is notorious that rents are much higher than in England, not only for small occupations, but for extensive farms; and that the tenants have complained less of the times than their neighbours in the south. It may be worth while to inquire into the cause of this, for the low price of corn must affect the Scotch farmer equally with the English. One great difference between the Scotch and the English farmer is, that the former gets work done at a cheaper rate than the latter. The Scotch labourer is fully as well fed, and clothed, and lodged, as the English; but he has less money to spend at the alehouse. He is paid, not in a certain sum every Saturday, but in comforts, in the keep of a cow, in a certain number of rows of potatoes, a certain quantity of grain, a cottage to live in, and oatmeal to feed his family; and above all, as a general rule it must be admitted that he is a man of greater intelligence. The horses of a Scotch farmer are well fed; they are always in good condition. They work ten hours in a day at two yokings. All this is worth 25 per cent. on the whole labour of the farm, as Arthur Young has very judiciously calculated, when he gives the expense of labour on the farm of a gentleman, compared with that on the land of a farmer who works with his men. (See 'Farmer's Guide.') The moral effect of an interest in the work to be done, when opposed to that of a perfectly distinct and often hostile interest, will readily account for so great a difference

But besides this the Scotch farmer has perhaps more commonly than the English man the advantage of a scientific education, and of a knowledge of the principles of his profession; and with the shrewdness peculiar to his country, he knows how to take advantage of every favourable circumstance. He has also been taught to calculate, and will soon discover where there is a profit or a loss. All this has kept up rents to a much higher level than in England.

The price of agricultural produce throughout Great Britain, and even Ireland, is brought very nearly to an equality, the only difference being occasioned by the means of transport. But the price of labour still varies much, and this is owing to local circumstances, which it is hoped will gradually cease.

Farm Accounts.—In proportion as the management of a farm requires more skill, and the various operations become more complicated, so the necessity of great accuracy in the accounts becomes more evident. The manner in which farm accounts should be kept deserves therefore particular attention.

Many farmers, who are not devoid of intelligence, and who are anxious to ascertain their gain or their loss in cultivating the land which they have hired, have no other means of ascertaining this than the balance of their account of receipts and expenditure. If they have separated the accounts of their private establishment from that of their farm, they think that they have done all that is required, and at the end of the year they can tell accurately how much they have gained or lost by their farm. But ask them to account for this gain or loss, and they can give no answer. If a tradesman, who has a capital in business equal to that of a farmer of a considerable number of acres, were to keep accounts in this manner, and become a bankrupt, no one would hesitate in saying that he failed because he kept no regular accounts. He had no greater stake than the farmer, and his transactions were perhaps less varied: if he kept no clerk, he should have attended better to the accounts himself. The same may be said of the farmer; and if a man who has a floating capital of 2000*l.* does not think it worth his while to keep detailed accounts, it is no great wonder if he is involved in difficulties. But it may be said that agricultural accounts are very simple, and that any one can keep them. So are merchants' accounts at first sight. Nothing is simpler than to put down what is bought and sold, what is the profit on each transaction, and the sum is the profit on the whole. But merchants know that to keep this very simple account many books, many entries, many checks, and consequently many clerks, are required. In a lesser degree this is true in a farm. It is easy to know what is bought and sold; what is expended or produced; but it requires very minute accounts to ascertain what part of the farm gives a profitable return, and what is the cause of loss. There may be a profit on the crops and a loss on the stock, or *vice versâ*. The money expended on improvements or adventitious manure may have produced an increase which is proportionate to the outlay, and which affords a good interest; but it may also be a decided loss. How is this to be ascertained, except it be by accurate accounts? The expense of keeping accounts is much overrated. A clerk who has his board and 30*l.* a year is generally a young man who has some education. He is useful in seeing that the operations ordered by the farmer are duly executed. He is a trusty overseer, and, as he has his accounts in his thoughts, he is most likely to detect the cause of any loss, from a want of attention in subordinate agents; his salary is therefore well earned, and the farmer will not think it thrown away. In whatever manner the accounts are kept, whether by the farmer himself or by a clerk, method is of great importance: and whatever may be said against it by those who do not know its value, there is no system of accounts which can be compared with the well-known method of double entry, by which every account, and indeed every entry, is effectually checked. [BOOK-KEEPING.] The principle of this method is so simple, that the slowest arithmetician cannot be confused by it, and it is so perfect that no error can escape its scrutiny. As applied to agricultural accounts, which are simple in their nature, it becomes so clear, that if once adopted it is impossible that it should ever be abandoned. The satisfaction of a perfect proof of the correctness of the accounts is so great, that no one who has ever experienced it will be satisfied with any other method.

In the accounts of a farm there are many separate items to be taken into consideration. There *may* be a separate account kept for every field. There should always be one for every crop of which the rotation consists. There is an account of the labour of men and horses; of the produce of the dairy; of the stock purchased to be fatted, or sold again in an improved state. In short the divisions of the general account may be increased without limit. The more subjects there are to furnish items for an account, the more difficult it is to strike a balance, but, with a little attention and perseverance, it may be done; and he who keeps very correct accounts will always be the first to discover any impending evil, and to take measures to provide against it.

The basis of all the accounts is a daily journal of every transaction, which must be collected from all the labourers and agents employed. M. de Dombasle, at his celebrated farm of Roville, in France, had all his principal servants and his apprentices assembled every evening after the day's work was over. Each man gave an account of the work done by him or under his superintendence, which was written down by the clerk. The orders for the next day were then given, and every one returned to his lodging or his home. In the course of the next day the clerk entered all that was in the journal into a book, where every person employed had an account; every field had one; every servant and domestic animal had one; and every item which could be separated from the rest was entered, both as adding to the account or taking from it. For example, the milk of the cow was entered daily. The quantity of butter, butter-milk, and skimmed-milk, which it produced was also entered; and these two accounts checked one another. Any error was immediately detected, and the knowledge of this prevented mistakes. An entry should be made of every particular operation in each field, that the farmer may know which is his most profitable land. The number of ploughings, the quantity of manure, the state of the weather, and all other circumstances which may influence the return should be carefully noted, in order that it may be clearly seen whether any experiment or deviation from the usual routine is advantageous or otherwise. Thus all real improvements may be encouraged, and uncertain theories detected by the result.

The most important circumstance which influences the profits of a farmer is the cost of his team and the wages of his labourers. These vary in different situations so much, that they greatly influence the rent which he can afford to give for the land. In some parts of the country the horses are so pampered that they can scarcely do a day's work as they ought. In others they are over-worked and badly fed. Either extreme must be a loss to the farmer. In the first case, the horses cannot do their work, and they consume an unnecessary quantity of provender; in the other, they are soon worn out, and the loss in horses that become useless or die is greater than the saving in their food, or the extra work done by them. A horse properly fed will work eight or ten hours every day in the week, resting only on Sundays; by a judicious division of the labour of the horses, they are never over-worked, and an average value of a day's work is easily ascertained. This, in a well-regulated farm, will be found much less than the common valuations give it. It is here that most of the errors are to be detected in the accounts of the expense of cultivation given in evidence before parliament, without any intention to deceive in those who gave the accounts. There have been printed forms invented in order to render the accounts more simple as well as more comprehensive. Forms may be of use to enter minute details, and each superintendent labourer may have a form of entry for the work which he performs or superintends; but the ledger should be kept exactly as that of a mercantile man, and be frequently balanced to ensure correctness. This is a thing which cannot be too strongly recommended to young farmers.

When a farm has been agreed for as far as rent is concerned, there are always conditions in a lease, which it is of great importance to the farmer to understand fully. It is necessary that the landlord should have some security against the wilful deterioration of his land by a dishonest tenant, but agents are too apt to cramp the tenants by prescribing the exact mode of cultivation without giving the tenant sufficient scope to try improved methods, which may ultimately be highly beneficial to all parties. If the landlord can ensure that his land is in the hands of an intelligent tenant, and a man of principle as well as skill, that will secure the application of the proper quantity of manure, and that it shall be well tilled and kept free from weeds, he need not have any other protection, unless it be for the last two or three years of the lease, when the tenant might be induced to overcrop the land, and thus exhaust it.

In entering on a farm there is often a heavy demand on the in-coming tenant for work done by the predecessor, for a supposed remainder of manure, and various other items, which are usually settled by reference to the custom of the country. Some general rule is required to regulate all these demands, which are often exorbitant, and cripple the in-coming tenant in his capital. It is just that an out-going tenant should be repaid for any permanent improvement which he has made, and of which he has not reaped the whole advantage, and that he should be encouraged to keep up the proper cultivation of the land, so that the in-coming tenant may be able to continue the regular course. But this he will not do, unless he expect to be remunerated. On the other hand, it is also just that the in-coming tenant should not pay for work slovenly done, or for supposed remnants of manure which do not exist in the land. We have known instances where the valuation of all the items to be paid for by the in-coming tenant greatly diminished his capital, and crippled his operations for several years. There should therefore be a separate stipulation on this head before a farm is finally hired. [TENANT RIGHT.]

FARMERS GENERAL, Fermiers Généraux, was the name given in France under the old monarchy to a company which farmed certain branches of the public revenue, that is to say, contracted with the government to pay into the treasury a fixed yearly sum, taking upon itself the collection of certain taxes as an equivalent. The system of farming the taxes was an old custom of the French monarchy. Under Francis I., the revenue arising from the sale of salt was farmed by private individuals in each town. This monopoly was first assumed by Philippe de Valois, in 1350. Other sources of revenue were likewise farmed by several individuals, most of whom were favourites of the court or of the minister of the day. Sully, the able minister of Henry IV., seeing the dilapidation of the public revenue occasioned by this system, opened the contracts for farming the taxes to public auction, giving them to the highest bidder, according to the ancient Roman practice. By this means he greatly increased the revenue of the state. But the practice of private contracts through favour or bribing was renewed under the following reigns; Colbert, the minister of Louis XIV., called the farmers of the revenue to a severe account, and by an act of power deprived them of their enormous gains. In 1728, under the regency, the various individual leases were united into a Ferme Générale, which was let to a company, the members of which were henceforth called Fermiers Généraux. In 1759, Silhouette, minister of Louis XV., quashed the contracts of the farmers general, and levied the taxes by his own agents. But the system of contracts revived: for the court, the ministers, and favourites, were all well disposed to them, as private bargains were made with the farmers general, by which they paid large sums as douceurs. In the time of Necker, the company consisted of 44 members, who paid a rent of 186 millions of livres, and Necker calculated their profit at about two millions yearly, no very extraordinary sum, if correct. But the revolution swept away the farmers general, and put an end to the system of farming the revenues; it equalised the duties and taxes all over France; but the monopoly of the salt and tobacco has remained, as well as the duties on provisions, cattle, and wine, brought into Paris and other large towns, and the right of searching by the octroi officers, if they think fit, all carriages and individuals entering the barriers or gates of the same.

The system of farming the taxes, although generally disapproved of, is still continued in some European states. Not many years ago the custom-house duties at Naples were farmed by private speculators.

The Roman system of levying taxes, at least after the Republic had begun to acquire territory out of Italy, was by farming them out. In the later period of the Republic, the farmers were from the body of the equestrian order. Individuals used to form companies or associations for farming the taxes of a particular district; the taxes were let by the censors for a period of five years. They were probably let to those who bid highest. These farmers were called publicani, and by the Greek writers telonæ (τελῶναι), which is rendered by publicans in the English version of the New Testament, where they are appropriately classed with sinners, for they were accused of being often guilty of great extortion. These tax-collectors in the province were, however, only the agents. The principals generally resided at Rome, where the affairs of each association (societas) were managed by a director called a magister. The individual members held shares (partes) in the undertaking. There was also a chief manager in the province or district of which the company farmed the tax, who was called pro-magister.

There are no means of knowing what proportions of the taxes collected reached the Roman treasury (ærarium). Numerous complaints of the rapacity of the publicani or their agents occur in the classical writers. These publicani were the monied men of the late Republic and the early empire, and their aid was often required by the state for advances of money when the treasury was empty. Part of the maladministration probably came from the publicani sub-letting the taxes, which seems to have been done, sometimes at least.

FARTHING. [MONEY.]

FARTHINGALE, or VARDINGALE, a hoop, a circle of whalebone formerly worn by ladies to spread the petticoat to a wide circumference. Strutt, in his 'Manners and Customs,' vol. iii. pp. 84, 86, tells us that among the men, early in the reign of Queen Elizabeth, the wearing of great breeches was carried to very absurd and ridiculous lengths; and the ladies, that they might not be behind-hand with the gentlemen in fantastical taste, invented the large hoop farthingales as a companion to the trunk hose or breeches. The farthingale afforded the ladies a great opportunity of displaying their jewels, and the other ornamental parts of their dress, to the utmost advantage, and for that reason obtained the superiority over the closer habits and the more simple imitations of nature.

Bulwer, in his 'Artificial Changeling,' says, when Sir Peter Wych was ambassador to the Grand Signior from King James I., his lady was with him at Constantinople: and the sultaness, having heard much of her, desired to see her; whereupon Lady Wych, accompanied with her waiting women, all of them dressed in their great farthingales, which was the court-dress of the English ladies of that time, waited upon her highness. The sultaness received her with great respect: but wondering much at the extension of her hips, inquired if that shape was peculiar to the women of England; to which the lady replied, that the English women did not differ in shape from those of other countries: and, by explaining to her the nature of the dress, convinced the sultaness that she and her companions really were not so deformed as they appeared to be. (Strutt's 'Habits of the People of England,' vol. ii.)

The farthingale, however, if not then, was at least subsequently worn through Europe. The French farthingale had the name of *Hausse-cul*; see Cotgrave. Lascells, in his 'Voyage of Italy,' 12mo., 1655, p. 96, says, "I found all the great ladies here to go like the donnas of Spain in guardinfantas, that is, in horrible overgrown vertigals of whalebone;" and Pepys, in his 'Diary,' notices the strangeness of those worn by the ladies who came over from Portugal with Charles the Second's queen. The hoop, the successor of the farthingale in England, went out at the beginning of the reign of George IV., who forbade its being worn at court. In 1858 and 1859 a modified revival took place. The hoop was no longer worn of the same size from the hips, but, under the name of crinoline, began a little larger than the body and swelled to an enormous size near the feet.

FASCES. [CONSUL; DICTATOR.]

FASCINES (*Military*) are bundles of strong brush-wood, employed chiefly for the purposes of reveting the epaulements of batteries and covering the roofs of field-magazines and blindages; and also with gabions to increase the heights of trench parapets, and to make temporary roads over marshy ground.

They are formed by placing the rods side by side in a cradle made of trestles placed about 4 feet apart, and compressing them by means of two levers connected by a chain, which is passed round the bundle: the whole is secured by withs or binders of spun yarn, which are placed 18 inches asunder. Fascines are commonly about 8 or 9 inches in diameter, and, when made, are 18 feet long; but they are then, if necessary, cut by the saw into parts of any required lengths, which are generally 6 feet or 12 feet. A fascine of the longest kind is sometimes called a saucisson.

When fascines serve for the revetment of a battery, they are usually laid horizontally, one line above another, against the interior slope of the epaulement, to which they are attached by pickets driven through them into the earth.

FASCINES, in *Civil Engineering*. A species of light defence (applied to the earthworks thrown up for the purposes of closing small branches of rivers, or of regulating the flow of the water), composed of small twigs bound together in bundles, and fastened to the ground by means of stakes and withes, is known among civil engineers by the name of *fascine work*. The bundles of twigs are made from the clearings of underwood and of dwarf trees, such as the ash, oak, hazel, alder, willow, thorn, bramble, &c., of about six or eight years old, the butt ends of which are all placed at one end, and in no case should the branches exceed 4 or 5 inches in diameter. The diameter of the bundles may vary between 1 foot 6 inches to 4 feet 6 inches at the larger end, and their length would, under these circumstances, range between 5 and 10 feet; the twigs being retained in their position by means of withes (or twisted twigs which tie the bundles together), placed at intervals of from 1 foot 4 inches to 1 foot 8 inches from one another. These bundles, or fascines, are either placed by hand upon the surface to be protected, or they are formed into species of rafts which are floated over the position they are intended ultimately to occupy, and are then sunk upon it, by being loaded with stones or gravel. The stakes or pickets are then driven through the bed of fascines into the bank, and they are connected together by stouter withes, which pass alternately round the heads of the stakes, in such a manner as to form square cases, to be subsequently filled in with rubble. It is supposed that the species of matting thus formed adapts itself with ease to the irregularities of the surface of the earthworks; but its principal advantage seems to consist in the fact, that it distributes the weight of the pitching course over the whole area, and thus prevents it from sinking into the body of the earth.

Fascines are much used by the Dutch, German, and French engineers; especially in the works executed for the protection of the banks of the Rhine. A description of the various systems adopted in the hydraulic works of that river will be found in 'Les Annales des

Ponts et Chaussées,' for 1833; or the reader may refer to Belidor's 'Architecture Hydraulique,' or to Sganzin's 'Cours de Construction, edité par Reibell.' Sometimes civil engineers of the Continent employ large fascines, which form, in fact, baskets filled with gravel, and are known by the local name of *saucissons;* or they use large square or triangular prisms to form the hearting of their banks. It is on the shores of the Lower Rhine especially that the fascines are formed into gigantic rafts, as above mentioned, of from 3000 to 4000 yards superficial, which are subsequently floated over their intended position, and sunk by the addition of gravel, or stone pitching. The Dutch engineers frequently use bundles of reeds for the same purposes as the fascines, at least in the protection of exposed surfaces of their dykes; whilst they also occasionally line the surface of a slope, intended subsequently to be pitched, with bundles of straw, when the price of fascines is so great as to render their use impracticable.

FAST, abstinence from food, more particularly used for such abstinence as a religious observance; from the Anglo-Saxon *fæstan.*

Religious fasting has been practised in almost all ages and all countries. Moses appointed that of the Day of Expiation for the Israelites. Herodotus (ii. 40) and Porphyry, give us details of the Egyptian fasts. Among the fasts of the primitive Christians, the greatest was that of Quadragesima, or Lent: but they likewise observed the *Jejunia quatuor temporum*, or fasts of the four seasons.

The fixed days appointed by the church of England for fasting are, first, the Forty days in Lent: second, the Ember days at the four seasons, being the Wednesday, Friday, and Saturday, after the first Sunday in Lent, the Feast of Pentecost, September 14th, and December 13th; third, the three Rogation days, being the Monday, Tuesday, and Wednesday before Holy Thursday; fourth, all the Fridays in the year except Christmas-day. Other days of fasting are occasionally appointed by royal proclamation. The Long Parliament appointed a fast on the last Wednesday of every month.

The Roman Catholics, the Greek Church, the Jews, the Mohammedans, the Buddhists, all keep certain fasts, as a religious observance; that of the Mohammedans being very severe.

FASTI were marble tables at Rome, on which were inscribed the names of the consuls, dictators, censors, and other principal magistrates of the republic. Fragments of these tables have been collected, and are ranged along the walls of one of the halls in the palace of the Conservatori on the Capitol. The deficiencies in the series of the consuls have been supplied by means of the historians, and by consulting monumental inscriptions. Several learned men in modern times have compiled fasti, or chronological tables of the Roman consuls. Among the most learned and accurate of these compilers is Sigonio of Modena, who published his 'Fasti Consulares ac triumphi acti a Romulo rege ad Titum Cæsarem,' fol., 1559; with a dissertation 'de nominibus Romanorum,' a work of great erudition and exact criticism. Pighius published 'Annales Magistratuum et Provinciarum S. P. Q. R. ab Urbe condita,' fol., 1599. Labbe, in his 'Bibliotheca Nova,' published 'Fasti Consulares' out of a MS. of the college of Clermont. Other editions of the Fasti have been made from various sources. Between these lists occasional discrepancies occur as to the names of some of the consuls, and the particular years of their consulships; for, notwithstanding the labours of critics and antiquaries, there is still some uncertainty about Roman chronology. The word Fasti is often used as synonymous with the annals, or chronicles of a nation. The 'Fasti Hellenici,' and 'Fasti Romani,' by H. F. Clinton, are valuable works of this description. [Clinton, H. F., in Biog. Div.]

The Romans had another kind of fasti, which they called 'Fasti minores,' a kind of almanacs, in which were registered the periodical festivals, games, official days for business, &c. Ovid wrote a poem explanatory of these fasti, which he dedicated to Germanicus, and in which he described the origin of the festivals, and the recollections, either happy or calamitous, connected with the various days of each month. The poem, as we have it, is in six books, one for each of the first six months in the year; the rest is unfortunately lost.

FASTING. [Abstinence.]

FATA MORGANA. [Reflexion and Refraction, Extraordinary Atmospheric.]

FATALISM. This term is used to express an article of philosophical religion, and usually signifies that the successive actions of mankind, and even the successive operations of the powers of nature, are under the guidance of some superior almighty power, so that these *successions* and the actions themselves are entirely independent of each other. This doctrine has been embodied in all religious systems, though very different names have been given to the governing power. The Greeks called it *moira* or *ananke*, and the Romans called it *fate;* their mythology also mentions a Demiurgus, who had formed the gods. All the ancient religions of Asia recognise a similar fate, something mightier than the gods, to whom it dictates laws; such, for example, as the alternating governments of Ormuzd and Ahrimanes in the Persian mythology, &c. Among the Hebrews the Pharisees were fatalists, the Sadducees materialists, and the Essenes deists. The old Germanic religion of Odin modified this fate, and brought it nearer to the idea of the government of the world by a deity, identifying it with their highest god, whose name was not to be pronounced. From this point fate changes to what is called predestination (in opposition to chance), which idea is only a mitigated fate, distinguished, however, from genuine fatalism in proceeding directly from God, and not from fate. This belief in predestination was taught by Mohammed, and his followers have retained it. Roman Catholicism has no trace of this doctrine, but it is held by the Calvinists, and to a certain extent at least by the church of England.

The doctrine of fatalism, as is well known, has been frequently and effectively used both by ancient and modern poets.

Intimately related to fatalism is the doctrine of the immediate and direct intervention of Providence in the government of the world. According to this doctrine the *consequences* of the actions of mankind depend wholly upon the actions themselves; God, however, is able so to conduct these consequences, that collectively they shall result in good, and conformably to his purpose. To comprehend this working precisely is impossible for man, since his mental powers are not sufficiently extensive, and this dogma must therefore be a matter of faith. This doctrine is held by many Christian sects, and in the Bible there are passages strongly in favour of such special intervention; for example, Matthew x. 29, "Are not two sparrows sold for a farthing? and one of them shall not fall on the ground without your Father."

The third or deistical interpretation of this doctrine teaches the complete non-intervention of the Deity in the affairs of the world or of mankind: we may also call this doctrine the doctrine of theological chance, which may still be consistent with that of physical necessity, according to Kant. The doctrine of physical necessity was advocated by Hobbes, and served for the foundation of the charges against him of deism and atheism.

If we consider these doctrines in a philosophical point of view we may come to the following results:—The theological theories of fatalism, predestination, the immediate government of God, and his non-intervention, evidently bear an analogical relation to the political systems of despotism, constitutional monarchy, and republicanism. Accordingly as every one may have grounds for being an adherent of one of these political systems, so may he also have grounds for being a follower of one of these theological views. According to the ideas and investigations of the author of this article, God may have positively fixed, before any creation of the world, the eternal ideas, or the relations of things to each other within the circle of which nature and human intelligence have to move. These ideas are (1) for nature, self-preservation, or continuance, of which the product is attraction, &c.; regularity, producing crystallisation, &c; and adaptation to purposes, producing organisation, &c.; (2) for human intelligence, self-love, beauty, and virtue. In so far as nature and humanity with all their efforts cannot move out of this sphere of ideas, so far fatalism and predestination exist. The efforts of nature to adapt means to ends, and the endeavours of the wise after virtue (or human happiness) appear to produce an ever-increasing progression, and in this sense they constitute an intervention of Providence—since nature being wholly bound, and God absolutely uncontrolled, man stands between both; so that though he is not absolutely free, yet he is free to work his ultimate ends out of himself; he is free whenever he acts morally, and he is not free whenever he acts immorally (or rather physically), and he may thus arrive at the consciousness that his state in another world entirely depends on himself. With this conviction every species of intervention would appear less harsh towards him, and without these grounds he may be doubtful whether any direct intervention exists with respect to worldly affairs.

An intervention of any other kind than that of God would lead to the doctrine of demons and spirits.

FATHER. [Parent and Child.]

FATHERS OF THE CHURCH is the name given to the early teachers and expounders of Christianity, who lived between the second and the sixth centuries of our æra, and whose writings are looked upon as possessing considerable authority in matters of faith. The earlier, or "primitive fathers," as they are sometimes styled, to distinguish them from the fathers of the fourth and fifth centuries, and who followed close upon the apostolical age, or the age in which the Apostles lived and died, are generally reckoned as follows. 1st, Clemens Romanus, or Clement I., bishop of Rome, who died about A.D. 100. 2nd, Ignatius, bishop of Antioch. 3rd, Polycarpus, bishop of Smyrna. 4th, Justinus, or Justin Martyr. 5th, Theophilus, made bishop of Antioch about 169, died about the beginning of the reign of Commodus: there is extant by him a work in three books, addressed to Autolycus, a heathen friend of Theophilus, whom he endeavoured to convert to the Christian faith. 6th, Irenæus, bishop of Lyon. 7th, Clemens, Titus Flavius Alexandrinus. 8th, Cyprian, bishop of Carthage. 9th, Origen of Alexandria. 10th, Gregorius, called Thaumaturgus. 11th, Dionysius, bishop of Alexandria, also a disciple of Origen: was banished under Valerian to the deserts of Libya, but was restored to his see under Gallienus, was engaged in controversy with Sabellius, Nepos, and Paul of Samosata, and died A.D. 265: of his numerous writings only fragments remain. 12th, Tertullianus of Carthage.

We now come to those Fathers of the Church who flourished in the fourth century, after Christianity had become the religion of the Empire, an age which may be styled the Augustan age of ecclesiastical literature, for the number and the merits of the writers whom it produced. The fathers of this period are generally ranged in two classes—Fathers of the Greek or Eastern Church, and Fathers of the

Latin Church. The former are: 1st, EUSEBIUS of Cæsarea. 2nd, ATHANASIUS, bishop of Alexandria. 3rd, BASILIUS, bishop of Cæsarea. 4th, GREGORIUS of Nazianzus. 5th, GREGORIUS, bishop of Nyssa. 6th, CYRIL, bishop of Jerusalem. 7th, CHRYSOSTOM, ST. JOHN, patriarch of Constantinople. 8th, EPHIPHANIUS, bishop of Salamis. 9th, CYRIL, bishop of Alexandria. To the above must be added Ephraim the Syrian, deacon of Edessa, who died about 378, and whose works have been published in the original text by Assemani.

The Fathers of the Latin Church are: 1st, LACTANTIUS. 2nd, HILARIUS, bishop of Poitiers. 3rd, AMBROSE, archbishop of Milan. 4th, JEROME, the translator of the Bible. 5th, AUGUSTINE, bishop of Hippo. With Augustine the list of the great Fathers of the Church is generally considered as terminating, although this title has been also bestowed on some subsequent prelates and theologians; but these, such as Bernard, Thomas Aquinas, &c., are more properly distinguished by the name of Doctors of the Church.

Of all the fathers whose names in the foregoing lists are printed in small capitals there will be found notices in the BIOGRAPHICAL DIVISION.

The study of the Fathers is interesting and important not only to theologians, but to those who would examine carefully the philosophy and the state of society in their time.

FATHOM. [WEIGHTS AND MEASURES.]

FATTY ACIDS. Fats and fixed oils consist for the most part of glycerin united with an organic acid, and when such fats and oils are boiled with basic substances, especially with the alkalies and alkaline earths they are decomposed, the acid uniting with the base, whilst the glycerin is set at liberty. This process of decomposition is commonly termed *saponification*, because it is the one essentially employed in the manufacture of soaps. The acids thus extracted from the fats and oils are frequently spoken of under the name of *fatty acids*. They belong to two distinct groups of organic acids, namely, to the series having the general formula, $CnHnO_4$ and to that having the general formula, $CnH(n-2)O_4$. By the action of oxidising agents upon some of the members of these groups, a third family of acids of the form $CnH(n-2)O_8$ is produced. The acids belonging to the latter family are bibasic. The following list gives the names and formulæ of the members of these three series of acids :—

Acids having the formula $CnHnO_4$. Monobasic.	Acids having the formula $CnH(n-2)O_4$. Monobasic.	Acids having the formula $CnH(n-2)O_8$. Bibasic.
Formic . $C_2H_2O_4$		
Acetic . . $C_4H_4O_4$	. . . . .	Oxalic . . $C_4H_2O_8$
Propionic . $C_6H_6O_4$	Acrylic . $C_6H_4O_4$	
Butyric . $C_8H_8O_4$	. . . . .	
Valerianic . $C_{10}H_{10}O_4$	. . . . .	Succinic . $C_8H_6O_8$
Caproic . $C_{12}H_{12}O_4$	Angelic . $C_{10}H_8O_4$	Adipic . $C_{12}H_{10}O_8$
Œnanthylic $C_{14}H_{14}O_4$	. . . . .	Pimelic . $C_{14}H_{12}O_8$
Caprylic . $C_{16}H_{16}O_4$	. . . . .	Suberic . $C_{16}H_{14}O_8$
Pelargonic $C_{18}H_{18}O_4$		
Rutic . . $C_{20}H_{20}O_4$	. . . . .	Sebacic . $C_{20}H_{18}O_8$
Lauric . . $C_{24}H_{24}O_4$		
Myristic . $C_{28}H_{28}O_4$		
Palmitic . $C_{32}H_{32}O_4$	Physetoleic $C_{32}H_{30}O_4$	
Stearic . . $C_{36}H_{36}O_4$	Oleic . . $C_{36}H_{34}O_4$	
Arachidic . $C_{40}H_{40}O_4$		
Cerotic . . $C_{54}H_{54}O_4$		
Melissic . $C_{60}H_{60}O_4$		

Detailed descriptions of these acids will be found under their respective names.

FAULT. [MINING.]

FAUN, FAUNUS, was the name given in the Roman mythology to the gods or genii of the woods, corresponding with the Panes of the Greek mythology. The Fauni were supposed to be the descendants of Faunus an old mythical king of Latium, who resided in the forest Albunea with his wife Fauna or Fatua, near the pond of sulphureous water which is between Rome and Tivoli; and who were both gifted with the faculty of prophesying. In subsequent ages Faunus was worshipped as the god of the fields and flocks; and a festival, called the Faunalia, held in honour of him by the country people and agriculturists on the 5th of December, was a scene of great mirth and feasting. The forest of Albunea continued to be the Delphi of Latium, and the oracles were delivered by a voice issuing from its recesses. (Virgil, 'Æneid,' vii. 82, &c.) Several statues in most European museums are believed to represent Fauni, but many usually called Fauns were more probably intended for Greek satyrs. [SATYRS.] Among the most remarkable are those in the gallery of Florence, and a very handsome one in the museum of the Capitol. The sleeping Faun of the Barberino is now in the gallery at Munich. The so-called Rondinini Faun in the British Museum is a very fine statue of its class: it is of the size of life, and in a dancing attitude, but the head and extremities are modern. This statue was formerly one of the most remarkable objects in the Rondinini palace at Rome. It was brought to England in 1826: and it would, it is said, have been brought here several years earlier, had not Canova used his influence to prevent its leaving Italy. Another very fine figure of a faun or satyr in the British Museum is that known as the 'Laughing Faun,' but the arms and both the legs below the knees are the work of a noted Italian "restorer" named Algardi, and are quite inconsistent with the original torso. A third, and equally celebrated statue in the same collection is that of a faun or satyr lying on his back, and known as the 'Drunken Faun': of this also the right arm and both feet are a restoration. There are some other statues and relievi of fauns in the British Museum which will sufficiently illustrate their general character: they are mostly collected in the Third Græco-Roman Saloon. The Fauni are almost invariably represented in playful attitudes, with a wild, mirthful, transient expression. Flaxman has in a single sentence sufficiently characterised them. "The Fauns are youthful, sprightly, tendonous; their faces round, expressive of merriment, not without an occasional mixture of mischief." ('Lectures on Sculpture,' p. 152.)

Rondinini Faun from the British Museum.

FAUSSE-BRAYE, a name given to the rampart which, constituting a second enceinte, is sometimes formed on the exterior of and parallel to that which constitutes the principal enceinte of a fortress.

In the ancient fortifications a bank of earth was frequently raised in the ditch, nearly or quite contiguous to the wall of stone or brick surrounding the place, in order to protect the latter against the battering-engines of the besiegers; and the Italian engineers of the 16th century make mention of a detached wall of masonry similarly situated, which seems to have been intended for a like purpose. This was then called a *fossa-brea*, and subsequently, by the French engineers, a *fausse braye*; the first term indicating a covering work in the ditch, and the other simply a secondary or advanced rampart.

In and immediately before the time of Vauban the fausse-braye constituted the exterior part of the general rampart of a fortress; its terreplein, or upper surface, was on, though sometimes a little above or below, the level of the country, and it carried a parapet for the protection of the defenders. The terreplein and parapet of the interior part of the rampart were several feet higher than those of the fausse-braye, and the interval between the two parapets was sometimes broad enough to allow room for artillery.

A good indication of the nature of this work may be obtained from the lower flanks of the bastions at Portsmouth, which are *double flanks*, and, in order to render the example complete, it is merely necessary to suppose these second parapets continued along the curtains and before the faces of the bastions.

The fausse-braye, thus formed, was most probably employed before the introduction of the covered way, a far more useful work: for the terrepleins and crests of parapets of the two works being in the same horizontal planes, it is evident that the fires could not be simultaneous, and consequently that neither the musketry nor artillery fire of the fausse-braye could be employed till the enemy were on the crest of the glacis. It also afforded to the enemy some facilities in escalading the rampart, by breaking the revetment into two steps, as it were; the first one, that of the fausse-braye, being about twenty-two feet, and when the enemy were on it permitting him to circulate along the rampart and rush in at more points than one at the same time. And again, the defenders of the fausse-braye would be easily enfiladed by the enemy's lodgments on the crests of the glacis three or four feet above them; and would be much injured by his shot and shell, which, striking the revetments behind them, would cause great splinters, and choke up the terreplein. On account of these defects, this kind of fausse-braye has been long since suppressed, except opposite the curtain, where it is supplied by the tenaille. [BASTION, *fig.* 1.] It should be observed, however, that Carnot and other more recent French engineers have proposed constructions which may be considered as partial revivals of the fausse-braye, but with circumstances which appear to render the work free from the defects above mentioned.

FEALTY. [FEUDAL SYSTEM.]

FEAR is the dread or apprehension of any object or event, which object or event however is sometimes purely imaginary. Absence of fear is resolution or courage. Absence of all *dread* would be a repose of the soul, for which, as it cannot exist, the language affords no term. Dread is a minor species of affright or terror, but of a more enduring nature. The highest and most excessive state of terror amounts to a total deprivation of consciousness, and produces death. If these definitions are correct, a smaller degree of terror would consist in a quickly-passing unconsciousness. Dread would consequently consist of a succession of recurring periods of unconsciousness, alternating with excessive rapidity with intervals of consciousness, of which only the total impression is perceived (as in the vibratory strokes of vibrating bodies in acoustics); this total impression constitutes dread. Fear is only distinguished from dread through the imminence of danger, and thence a fearful or a dreadful or frightful object are nearly synonymous. The longer these periods of unconsciousness endure in a state of fear or dread, the more powerful are the feelings, till at length (as in drowning persons, or in children who are much alarmed) total unconsciousness ensues, and, according to circumstances, death.

If these definitions of fear and dread are psychologically correct, they serve to explain all the consequent physiological phenomena. A violent blow upon the head deprives us of consciousness, by occasioning an interruption in the regular functions of the brain, through which recollection ceases, and unconsciousness ensues. Any horrible appearance to, or impression upon, the organs of sight may produce a similar effect; for if the nerves of vision are so powerfully affected as to re-act upon the brain, the regularity of its action is similarly destroyed and the same effects are produced as by a blow. It is the same with all the other senses; and it is worthy of remark, that these feelings (of fear or dread) evidently heighten the powers of the imagination. If therefore a powerful affection of the visual nerve will produce absolute terror, so may a smaller degree of terror produce the more lasting sensations of dread or fear, that is, interchanging pauses of consciousness and unconsciousness. With the brain and spinal marrow the nerves are connected which lead to the lungs, to the stomach, to the muscles, and other parts of the body. It is therefore not surprising that dread or fear should display itself in shortness of breath, irregularity of pulsation, an increased action of the heart, a disordered stomach, sickness, and powerlessness of the limbs.

Fear may be also produced through a disordered action occasioned by some local affection of the heart or the lungs, or through plethora or disorders of the blood, or through a general sickness, as in the cholera.

FEAST or **FESTIVAL**, an anniversary day of civil or religious joy; from the Latin *festum*.

Among the Jews, the feast of Trumpets, that of Expiation, the feast of Tabernacles, the feast of Dedication, the Passover, Pentecost, and the feast of Purification, were the principal. The modern Jews have a few more, but they are of later institution.

The Greeks, and more especially the Athenians, had an abundance of festivals. Such were the Aglauria, in honour of Aglauros, the daughter of Cecrops; the Artemisia, in honour of Artemis; the Dionysia, in honour of Dionysus; the Eleusinia, in honour of Ceres; and the Panathenæa, in honour of Athene: notices of the three last and most important of them will be found under their several headings.

The Roman festivals were of two kinds; first, those which were fixed or stated; secondly, those which were appointed annually on a certain day by the magistrates or priests. Of the former kind were the Agonalia, the Faunalia, Matronalia, Cerealia, Saturnalia, &c., through the several months; the latter were the Feriæ Latinæ or Latin holidays, the Paganalia in honour of the tutelary gods of the rustics, the Sementivæ in seed-time, and the Compitalia. Dion (ix. 17) observes that so large a portion of the year was taken up with sacrifices and holidays, to the great loss of the public, that Claudius abridged the number.

The Mohammedans, in addition to their weekly feast, or sabbath, which is observed on Friday, have two festivals of a more solemn kind; the feast of Victims, celebrated on the 10th day of the last month of their year, and the feast of Bairam.

With us, some of our festivals are immoveable, and others moveable. The immoveable festivals are Christmas Day, the Circumcision, the Epiphany, Candlemas or the Purification, the Annunciation of the Virgin Mary or Lady Day, All Saints, and All Souls. The greater part of what are called Saints' Days have long ceased to be celebrated, except in the calendar. The principal of the moveable feasts, and that by which the rest are guided, and from which they keep their proper distance, is Easter; the others are Palm Sunday, Good Friday, Ash Wednesday, Sexagesima, Ascension Day, Pentecost, and Trinity Sunday. The four feasts from which leases are usually dated, and quarterly payments made, are Lady Day, 25th March; the Nativity of St. John Baptist, June 24th; Michaelmas Day, September 29th; and Christmas Day, December 25th. In the Roman Catholic and Greek churches the festivals of the various saints are still preserved.

The reader who would know more of the English festivals at an earlier period, may consult the 'Liber Festivalis,' printed at Westminster by W. Caxton, sm. fol. 1483, which consists chiefly of a collection of sermons, preached to the common people upon them. See also 'Festa Anglo-Romana,' 12mo, London, 1678; 'Historia Sacra, or the Holy History, giving an exact and comprehensive account of all the Feasts and Fasts of the Church of England,' 2nd edit.; and Nelson's 'Fasts and Festivals.'

FEATHERS. In addition to their anatomical relation to the coverings of birds, the principal uses to which feathers are applied are for personal decoration, as plumes for ladies' head-dresses, or for the hats of military officers; as a soft and highly elastic material for filling beds, cushions, and pillows; or in the case of the larger quill-feathers, as writing-pens, or small tubes for the manufacture of hair-pencils, or similar purposes.

For the first of these purposes their elegant appearance is their great recommendation; for the second, to which only the smaller feathers are applied, their exquisite softness, and that elasticity and peculiarity of structure which renders them less liable to clot together, under the influence of pressure, than any kind of woolly or hairy substance which is applied to the same purpose, are their great recommendation; while the last-mentioned use depends on their possession of a hollow quill or barrel of a horny texture, which, though found in all feathers, is only sufficiently large and strong in those of the wings and tail to be useful for such a purpose.

Plumagery. Of the various kinds of feathers employed as plumes for head-dresses, the most important are those of the ostrich, of which there are various qualities, almost wholly procured from Africa. Those of the male bird are preferred, as being the whitest and most beautiful; those upon the back and above the wings being considered the best, those of the wings next in quality, and the tail-feathers the least valuable. The *down*, which is black in the males and gray in the females, consists of the smaller feathers from other parts of the body, which vary in length from four to fourteen inches. The finest white feathers of the female bird are somewhat gray towards the end, which lessens their value. The mode of preparing ostrich feathers for use, and of dyeing them of various colours, is briefly as follows: They are first washed or *scoured* by rubbing with the hand (being previously tied up in bundles) in a lather of white soap and water, and subsequently in clear water, as hot as the hand can bear. They are then bleached by three successive operations, the first being to immerse and agitate them well in hot water mixed with Spanish white, after which they are rinsed in three clear waters in succession; the second, which is termed *azuring*, passing them quickly through a bath of cold water containing a little indigo tied up in a fine cloth; and the third, *sulphuring*, or exposing them in a close vessel to the vapour of burning sulphur, in the same way as in the bleaching of straw hats and bonnets. The feathers are then dried by hanging upon cords, during which they are shaken from time to time to separate their fibres. To increase their pliancy the ribs are scraped with a bit of glass cut circularly; and to impart the requisite curly form to the filaments or fibres, the edge of a blunt knife is drawn over them. The dyeing is effected by various agents—logwood, copperas, and acetate of iron for black; indigo for blue; alum, Brazil wood, and cudbear for crimson; safflower and lemon-juice for pink; alum and Brazil wood for red; alum, turmeric, and weld for yellow, &c. For all colours except black, the feathers should be previously well bleached by exposure to the action of sun and dew, which is effected by cutting the end of the quill or tube to a sharp point, and sticking or planting the feathers singly in grass ground, where they are left for fifteen days.

Dr. Macgowan, United States consul at Ningpo, has recently given an interesting account of the plumagery or feather-working of the Chinese. Feathers are largely employed by that ingenious people in the decoration of metallic ornaments, chiefly for head-dresses. The lustre of the metal is softened by laying over it portions of a covering of blue feathers, representing flowers, insects, birds, and the like. The art appears to most advantage as practised by artificers whose occupation is the manufacture of garlands, chaplets, frontals, tiaras, and crowns of very thin copper, on which purple and blue feathers of gorgeous brilliancy are placed with much taste and skill. From the size of these ornaments, scope is afforded for the display of various figures. Dr. Macgowan describes in the following words the processes of this kind of feather-working :—"On the table at which the workman sits, he has a fasciculus of feathers, a small furnace with a few embers for keeping warm a cup of glue, a small cutting instrument like a screw-driver, a pencil or brush, and the articles, either silver, gilt, copper, tinsel, or pasteboard, which are to be feathered. The thumb and index finger being smeared with glue, the feathers are gently drawn between them, which stiffens the barbs, causing them to adhere firmly together; when dry, the perpendicular blade is drawn close to the shaft, dividing it from the barbed portion. Holding this cutting instrument as in writing *à la Chinoise*, the artist, by pressing on the strips of barb with the knife, cuts them into the desired size and shape, which is a work of some delicacy—the pieces being very small, in the form of petals, scales, diamonds, squares, and the like, and requiring to be of the same size as the particular spot on which they are to be laid. Besides fingering this tool in the manner described, he holds the pencil nearly as we do a pen, dips it into the glue, brushes the spot to be coated; then expertly reversing it, touches with its opposite point a morsel of feather, which is thus lifted up and laid on the part for which it was fitted. Care is requisite also in giving a proper direction to this twilled work; for such of course is the appearance presented by the barbs. The feathers most in demand for this purpose are from a beautiful species of *Alcedo*, brought from the tropical regions of Asia; they are employed for silver articles. Kingfishers of coarser plumage, and less brilliant hue, found throughout the country, are used for ornaments made of copper and pasteboard. Blue always greatly predominates over lighter or darker shades, relieved by purple, white, or yellow. . . . Sometimes two dragons extend from below the lobes of the ears, meeting above the forehead, the variegated scales of which are represented by minute portions of feathers of various hues; at others, beautiful flowers are interspersed with elegant mosaic. And then again the head attire appears animated; as with every turn of the fair one, tiny genii, birds, and insects are set in motion from springs and wires which retain them in the midst of the fairy-like garland. To increase the effect, these ornaments are studded with pearls, produced cheaply and in great abundance by artificial means in a fresh-water mussel." ('American Journal of Science and Art.')

Bed Feathers. The employment of feathers for stuffing beds was known in England at least three centuries ago. Goose feathers —which, owing to their superior elasticity, are preferred for this purpose—are considered best when plucked from the living bird; and in the districts where geese are chiefly kept, this cruel operation is repeated from three to five times in a year. While most writers condemn this practice for its apparent barbarity, and while some even assert that in cold weather many birds die in consequence of being subjected to it; others affirm, on the other hand, that the breeders, for their own profit, pluck only such feathers as are very near falling off, and the removal of which consequently gives but little pain, because as such as are firmly fixed have a little blood at the end, they are less valuable. Young birds are plucked as well as those of mature growth, early plucking being supposed to promote the rapid growth of the feathers. Goose feathers are divided into white and gray, the former being deemed the most valuable. The less valuable kind of feathers, known by the general name of *poultry feathers*, are obtained from turkeys, ducks, and fowls. Wild-duck feathers are both soft and elastic, but their value is impaired by the great difficulty of removing the disagreeable odour of the animal oil which they contain. Various methods are practised of cleansing feathers from their oil. Some manipulators use lime water; others lime in a different state. The purification of bed-feathers by the agency of steam is now much practised; in one method, which is secured by patent, and is applicable either to new feathers or to such as have become deteriorated by use, the feathers are so greatly improved in softness and elasticity that a much less quantity of them than of feathers prepared in the ordinary way suffices to make a good bed.

The softest and finest kind of feathers employed for bedding are those from the breast of the eider-duck, known in commerce as eider-down. [EIDER DOWN.] This exquisitely soft down should never be slept upon, as it thereby loses its elasticity, but should be used only as a covering. A similar substance, though in less quantity, is procured from the swan, the goose, and some other birds.

Quills for Pens. For the third of the above-mentioned uses of feathers the quills of the goose are most generally employed, though, for purposes where great size and strength are required, those of the turkey and swan are highly prized. When geese are plucked several times in a year for other feathers, the quills are only taken at the first plucking about the end of March. As taken from the bird, the horny substance of the barrel of the quill is covered, both internally and externally, with a vascular membrane, which adheres very closely to it, and the substance of the quill itself is opaque, soft, and tough. The quills must therefore be subjected to certain operations by which the membranes may be detached and dried up, and the barrel rendered transparent, hard, and somewhat brittle; previous to which they are sorted into *primes*, *seconds*, and *pinions*, the first of which consist of the largest and longest barrelled quills, and the others of such as possess these characteristics in a less degree. They are further sorted into right and left wing feathers, in order that all tied up in one bundle may have the same curvature; and before tying up for sale the *barb*, or feather proper, is usually stripped off from the inner edge of the stem, in order that they may lie compactly together. In a goose's wing only the five exterior quills are fit for making pens, and of these the first is the hardest and roundest, but the shortest, and the second and third are considered the best. Dutch quills are highly esteemed, as the Dutch were the first who hit upon the art of preparing them well, by clearing them, both inside and outside, from a fatty humour with which they are naturally impregnated, and which prevents the ink from flowing freely along the pens made with them. The Dutch employ hot cinders or ashes to attain this end; and their secret was preserved very carefully, but it at length transpired, and the process was then improved. In the improved method the barrel end of the quill is plunged for a few seconds in a sand-bath, heated to about 140° Fahr., and then rubbed strongly with a piece of flannel. After this it appears white and transparent. In another method the workman sits before a small stove fire, into which he thrusts the barrel of the quill for about a second. Immediately upon withdrawing it from the fire, he draws it under the edge of a large blunt edged knife, called a *hook* (shaped somewhat like a patten-maker's knife, and like it, having a fulcrum at one end, formed by a hook and staple, and a handle at the other end, by which pressure may be communicated), by which it is forcibly compressed against a block or plate of iron, heated to about 350° Fahr. By this process the barrel, which is rendered soft and elastic by the heat, is pressed flat, and stripped of its outer membrane, without danger of splitting. It springs back to its natural form, and the dressing is completed by scrubbing with a piece of rough dog-fish skin. The principal workman employed in this operation can pass 2000 quills through his hands in a day of ten hours. In a fourth method which is considered inferior as regards the quality of the quills for pen-making, although it makes them somewhat more pleasing to the eye, the quills are first stained yellow by steeping them for a night in a decoction of turmeric, then dried in warm sand, and subsequently scraped in the manner above described. Steaming for four hours has also been suggested as a good mode of dressing or preparing quills. By whatever process the external membrane is removed, that inside the quill remains, separated from it, and shrivelled up in the centre of the barrel, until it is cut open to convert it into a pen.

FEBRUARY, the second month of the year. Its name is derived from *februo*, to purify or cleanse. The Lupercalia were celebrated in this month. (Ovid, 'Fasti,' ii. l. 19, 31.) The Saxons called it *Sol-Monath*, because the sun's meridian altitude visibly increases in it.

February was not in the Calendar of Romulus. It was added to the year by Numa, who gave it the twelfth place in the Calendar. The Decemviri transferred it to the place in which it now stands. (Ovid, 'Fasti,' ii. l. 47.) Numa assigned twenty-eight days to it in order that the sum of the year might be an uneven number, according to a Pythagorean fancy. (Macrob. 'Saturnal.' li. i. c. 13.) In an ordinary year February has twenty-eight days; in bissextile, or leap-year, it has a twenty-ninth, or intercalary day, except once at the end of each period of four centuries.

FECIALES, in ancient Rome, were the messengers or heralds of war and peace; they belonged to the order of the priesthood, and their persons were held sacred even by enemies. When the Romans had or pretended to have grievances against another state, they sent one of the feciales, who clad in his solemn robes, entered the obnoxious territory or town, and in the presence of the assembled people, or of the magistrates and rulers of the country, stated the complaints of the Romans, and asked for reparation. A certain time, generally thirty days, was allowed for deliberation and for returning an answer, at the end of which the fecial herald came again, and if the answer was not satisfactory, he took to witness Jupiter and the other gods that he had religiously performed his duty, and that it was now the business of the Roman senate and people to decide upon the question. On his return to Rome he declared to the senate the result of his mission, and told them that they might now declare war if they thought proper. If war was decided upon, the fecial herald went again to the limits of the hostile state, and there, in presence of witnesses appealing to Jupiter and the other gods celestial and terrestrial, he protested against the injustice of that people and their obstinacy in refusing reparation, and declared that nothing now remained for Rome but to seek satisfaction by its own arms: he then threw a spear within the hostile boundaries, upon which war was considered as begun. When a treaty of peace or alliance was to be concluded, the presence of the feciales was likewise required, as with the Romans all political conventions partook of a religious character. The Etruscans and other ancient Italian nations had also their feciales. This institution had a beneficial effect, insomuch as it tended to humanise the system of warfare, and to prevent sudden and unexpected aggressions.

FECULA. [STARCH.]

FEDERATION. A federal union of sovereign states may be most easily conceived in the following manner :—

We will suppose that the sovereign power in any number of independent states is vested in some individual in those several states. These sovereign persons may agree respectively with each other and with all not to exercise certain functions of sovereignty in their several states, and to transfer these functions to be jointly exercised by the contracting sovereign persons. The consequence of such a compact will be that the contracting sovereign persons in their joint capacity will become sovereign in each state and in all the states. The several sovereign persons having for the time surrendered to the joint body certain powers incident to their several sovereignties are no longer severally sovereign in their several states. The powers surrendered to the joint body may be determined by written contract, the interpretation of which belongs to the joint body, yet in such a manner that there can be no valid interpretation unless the sovereign persons are unanimous; for if any number or majority could bind the rest, they might, by interpretation, deprive the several contracting persons of all the powers reserved to them by the contract. It follows also from the terms of the union, that any one party can withdraw from it at pleasure, and, as far as he is concerned, dissolve the union; for the essence of this union is the continuing consent of all.

This is the simplest possible form of a supreme federal government; one in which the contracting sovereign powers are individuals, and in which the sovereign persons in their aggregate capacity exercise the functions of sovereignty. Such a federation may never have existed, but any federation that does exist or can exist, however complicated it may seem, is reducible to these simple elements.

If the sovereign powers, instead of being in individuals, are in all the people of the respective states, the only difference will be that the functions of sovereignty, which in the first case we supposed to be exercised by the individual sovereigns in their joint capacity, must, in this case, be delegated to individual members of the sovereign body. The citizens of the several sovereign states must in the first instance of necessity delegate to some of their own body the proper authority for making the federal contract or constitution; and they must afterwards appoint persons out of their own body, in the mode prescribed by the federal contract, for executing the powers intrusted by the federal contract to persons so appointed. Thus the individuals who form the federal contract act therein severally as the agents of the sovereign states from which they receive their commission; and the individuals appointed to carry into effect the terms of the federal contract are the ministers and agents of that sovereign power which is composed of the several sovereign states, which again are composed of all the citizens. By whatever name of President, Senate, House of Representatives, or other name, the agents of the sovereign power are denominated, they are only the agents of those in whom the sovereign power resides.

When the sovereign power is so distributed, the question as to the interpretation of the federal contract may in practice be more difficult, but in principle it is the same. No one state can be bound by the interpretation of the rest, for if this were once allowed there would be no assignable limit to the encroachments of the states exercising sovereign power in their aggregate capacity. It is a clear consequence of the nature of the compact, whether the several sovereign powers are nations or individuals, that each contracting power must exercise its judgment on the interpretation of the instrument to which it is a party, and that no interpretation from which any power dissents can, consistently with the nature of the compact, bind that power.

In the case of complete dissent or disagreement by any one power, the contract is, by the very nature of its terms, at an end; for the contract being among sovereign powers, they cannot severally as such yield *obedience* to another sovereignty, which results from the aggregation of their several sovereign powers: their acts in their joint capacity must be acts of complete consent.

If the sovereign power in such a federal union has delegated the power of interpreting the written instrument of union to certain judiciary authorities, appointed under the federal compact for the purpose of carrying its provisions into effect, the several sovereign powers must still exercise, either by their legislatures or their judiciary authorities, their right to judge of the correctness of the interpretation, just as much as if the several sovereign persons, in the case first supposed, themselves exercised the functions of sovereignty in the supreme federal government.

What is commonly called the general government of the United States of North America is an example of a federation or federal government, or a supreme federal government. The contracting parties were sovereign states (the sovereignty in each state being in the citizens), which in their aggregate capacity formed a supreme federal government. The ministers for carrying into effect the federal government are the president and congress, and the judiciary of the United States. By the preamble to the constitution it is in fact declared that the "people of the United States" are the contracting parties.

The fifth article of the constitution provides that "The congress, whenever two-thirds of both houses shall deem it necessary, shall propose amendments to this constitution, or on the application of the legislatures of two-thirds of the several states, shall call a convention for proposing amendments, which, in either case, shall be valid to all intents and purposes, as part of this constitution, when ratified by the legislatures of three-fourths of the several states, or by conventions in three-fourths thereof, as the one or the other mode of ratification may be proposed by the congress; provided, &c., and that no state, without its consent, shall be deprived of its equal suffrage in the senate." From this article it is clear that the framers of the constitution did not fully comprehend the nature of the supreme federal government; for it is assumed by this article that the several states may be bound without their unanimous consent, which is contrary to conditions essentially implied by the nature of the union. This article involves also the inconsistency that the sovereign in any state may bind his successors: if the case of a federation of individual sovereign persons had been that to be provided for, the impossibility of the provision would have been apparent; but the impossibility equally exists when the contracting sovereign powers are respectively composed of many individuals, for the abiding consent is still the essence of the union that has been formed.

This is not the proper place to discuss the advantages and disadvantages of a supreme federal government, nor to examine into its stability. That it is necessarily deficient in one element of stability, namely, in there being a necessity for all the consenting parties to continue their consent, is evident: in this respect it is like a partnership for an indefinite period, which may at any time be dissolved by any one of the partners. Such a power, which is incident to the nature of the partnership, so far from being an objection to it, is a great advantage. So long as all the parties agree, they have the benefit of the union: when they cannot agree, they take instead of it the benefit of the separation.

It is also foreign from our purpose to consider what is the tendency, in a union like that of the United States, resulting from the powers placed in the hands of the president and congress by the states acting in their aggregate capacity. If such power were placed in such hands by sovereign persons originally severally sovereign in their respective states, as in the case first supposed, the vigilance of these persons in their aggregate capacity, though somewhat less than the vigilance of a single sovereign person, would probably prevent any undue assumptions of power on the part of those to whom they had delegated certain fixed powers. But the farther the several sovereigns, who in their aggregate capacity form this federation, are removed from those to whom they delegate certain powers, and the more numerous are the individuals in whom this aggregate sovereignty resides, the greater are the facilities and means offered to, and consequently the greater is the tendency in, their ministers and agents practically to increase those powers with which they may have been intrusted. In their capacity of ministers and agents, having patronage at their command and the administration of the revenue, such agents may gradually acquire the power of influencing the election of their successors, when their own term of office is expired, and may thus imperceptibly, while in name servants, become in fact masters. That there is such a tendency to degenerate from its primitive form in all social organisation, as there is in all organised bodies to be resolved into their elements, seems no sufficient reason for not forming such union and deriving from it all the advantages which under given conditions it may for an indefinite time bestow on all the members of such federation.

Federations of a kind existed in ancient times, such as that of the Ionian States of Asia, which assembled at the Panionium at certain times (Herodotus, i. 142); the Achæan confederation; the Ætolian confederation; and the Lycian confederation, which is described by Strabo (p. 664). The Roman system of fœderate states (*civitates fœderatæ*) is another instance of a kind of confederation; but it was of a peculiar kind, for Rome was neither absolutely sovereign over these states nor yet associated with them in a federation, as now understood. The relationship between Rome and the federate states rather resembled the relation of sovereign and subject than any other, though it was not precisely that.

A supreme federal government, or a composite state, is distinguished by Austin ('Province of Jurisprudence Determined') from a system of confederated states: in the latter, "each of the several societies is an independent political society, and each of their several governments is properly sovereign or supreme." It is easy to conceive a number of sovereign powers, such as the German states, assembling and passing resolutions which concern all the members of the confederacy, and yet leaving these resolutions to be enforced in each state by its own sovereign power. Such a union, therefore, differs essentially from a supreme federal government, which enforces its commands in each and all the states. As to the existence of a written constitution, as it is called, in the one case, and a mere compact in the other, that makes no essential difference; for the federal constitution, as we have shown, is merely articles of agreement, which only derive their efficacy from the continued assent of all the members that contribute in their aggregate capacity to form the sovereign power in such federation.

As to a system of confederated states, Austin adds, "I believe that the German Confederation, which has succeeded to the ancient empire, is merely a system of confederated states. I believe that the present diet is merely an assembly of ambassadors from several confederated but severally independent governments; that the resolutions of the diet are merely articles of agreement which each of the confederated governments spontaneously adopts; and that they owe their legal effect, in each of the compacted communities, to laws and commands which are fashioned upon them by its own immediate chief. I also believe that the Swiss Confederation was and is of the same nature. If, in the case of the German or of the Swiss Confederation, the body of confederated governments enforces its own resolutions, those confederated governments are one composite state, rather than a system of confederated states. The body of confederated governments is properly sovereign; and to that aggregate and sovereign body each of its constituent members is properly in a state of subjection."

FEE-FARM RENT. [RENT.]

FEE-SIMPLE. [ESTATE.]

FEE-TAIL. [ESTATE.]

FEELING. [TOUCH.]

FEES, certain sums of money claimed as their perquisite by official persons under the authority of various Acts of Parliament, and by prescription. The right to fees, as well as the amount payable in most cases connected with the administration of justice, has been regulated by several recent statutes.

Officers demanding improper fees are guilty of extortion. [EXTORTION.]

The rewards paid to barristers and physicians, attorneys and surgeons, for their several services, are called fees, which may be recovered by the three last-named by action. Barristers cannot recover their fees by any legal proceeding; nor can physicians, if they are members of a college of physicians which has enacted a bye-law to that effect. [COUNSEL; PHYSICIAN.]

FEHM GERICHTE, FEMGERICHTE, or VEHM GERICHTE, the celebrated courts of justice of Westphalia, which have been, on very slender authority, said to be the relic of an institution of Charlemagne, but which certainly flourished and possessed most enormous power and influence during the 13th and 14th centuries. It was chiefly confined to what was then known as Westphalia, which included nearly all the countries between the Rhine and the Weser, and extended from the mountains of Hesse on the south to Friesland on the north; and this district bore the mystic name of the *red earth* in the records of the time, though the exact derivation or meaning of the term is uncertain. It would seem that, whatever earlier institutions it may have been founded upon, the tribunal was first organised when, after the deposition and outlawry of the emperor Henry the Lion, the authority of the laws, both civil and ecclesiastical, gave way to force, which, in the hands of ignorance and rapacity, threatened society with dissolution. In order to check the audacity of those who, relying upon their power, thought themselves above the reach of the law, and for the protection of the defenceless and innocent, a secret tribunal was formed, called the sacred Fehme, or Fehm Gericht.

These tribunals arose from the like causes which formed the trade-guilds in towns, and the confederacy of the Hanse Towns, namely, the necessity of individuals following peaceful professions defending themselves by unions against the spoliation and tyranny exercised by the feudal nobility, and which neither the law nor the emperor was able to repress, nor, except in rare cases, to punish. When these confederations became sufficiently powerful to defend themselves, the neighbouring nobility were frequently desirous of becoming members of the community, in order that they might in some measure guide what they could no longer resist. It was in fact an early development of public opinion developed in forms peculiar to the period; and the sentences of the Fehm Gerichte itself, except that the institution was permanent, resembled in some of its features those of the Lynch-law in the back settlements of the United States of America. There was usually no concealment, the trial was held commonly in the open air, in the presence of an audience; and it was only on the conviction of an offender who failed to appear that his death was effected by the means which added so much mystery and terror to the judgments of the courts.

By the constitution of the tribunal, the Emperor of Germany was the nominal head, who was usually made a member of the Fehm on his coronation at Aachen: but very early the archbishop of Cologne was made the imperial lieutenant in Westphalia; and indeed it is stated that archbishop Engelbert was, in 1179, the first Freygraf. Under the archbishop were the tribunal lords (Stuhlherren), to each of whom a particular district was assigned, beyond which he had no jurisdiction. The Stuhlherr either presided in the courts himself or deputed a count (Freygraf) to take his place; for the country was divided into counties (Grafschaften), and every county had at least one Freygraf, who took an oath to judge truly and justly, and to be obedient to the emperor and his lieutenant. Next to the counts were the assessors or Schöppen, who formed the bulk of the society. These were nominated by the count, with the approval of the Stuhlherr, after having been recommended by two persons, already members of the tribunal, who vouched for the fitness of the candidate. The candidate was required to have been born in marriage, of free parents, to be a Christian, to be neither excommunicated nor outlawed, not to be involved in any process before the tribunal, not to belong to any spiritual order, and at first to have been a native of Westphalia; but latterly strangers were admitted. Kneeling bareheaded before the assembly, with his thumb and forefinger on a naked sword and a halter, he swore—

"I promise, on the holy marriage, that I will, from henceforth, aid, keep, and conceal the holy Fehms, from wife and child, from father and mother, from sister and brother, from fire and wind, from all that the sun shines on and the rain wets, from all that is between sky and ground, especially from the man who knows the law; and will bring before this free tribunal, under which I sit, all that belongs to the secret jurisdiction of the emperor, whether I know it to be true myself, or have heard it from trustworthy people, whatever requires correction or punishment, whatever is Fehm-free (that is, a crime committed in the county), that it may be judged, or, with the consent of the accuser, be put off in grace; and will not cease so to do, for love or for fear, for gold or for silver, or for precious stones; and will strengthen this tribunal and jurisdiction with all my five senses and power; and that I do not take on me this office for any other cause than for the sake of right and justice; moreover, that I will ever further and honour this free tribunal more than any other free tribunals; and what I thus promise will I steadfastly and firmly keep, so help me God and his Holy Gospel."

As soon as the neophyte had pronounced the oath, he was informed that the object of the association was to uphold peace, virtue, and honour against the open or concealed enemies of the law; and as the interest of the order required that the schoppen of the different counties and principalities should be known to each other, they had adopted a sign consisting of four letters, S.S.G.G., the signification of which is still involved in mystery. The neophyte was further presented with a rope, which he was obliged to carry in his left sleeve, and also a dagger, on which the four above-mentioned letters were engraved, together with other symbols. Moreover he was charged with the duty of accusing before the secret tribunal all those who could not be successfully prosecuted before the ordinary courts, and of executing capital punishment whenever required by the society to perform this duty.

The mode of proceeding against the accused was as follows: If the author of a crime absconded, or his residence was unknown, the schöppe was required to write four summonses, and post them on a cross road; but if the residence was known, the schöppe came at night, and nailed the summons with four nails, folded as a letter, containing an imperial farthing, on the man's door. He then rang the bell, and told the porter that he had brought a letter from the sacred tribunal for his master. The initiated could go through the country unimpeded, on foot or on horseback, for none was so daring as to stay or injure him. The summons required the accused to appear at a certain hour at the appointed spot, within a fortnight after its delivery, to answer for his base and criminal conduct before the sacred tribunal, or otherwise clear himself of the accusation; at the same time threatening to proceed against him for contempt in case of non-appearance. If the accused attended the summons, the schöppe who brought the accusation was called upon by the Freygraf to state all that he and his witnesses knew relating to the charge, after which the accused and his witnesses were heard. The judges assembled on a Tuesday in the open air. The count presided, and before him on the table lay a naked sword and a withy halter. On his right and left stood the clerks of the court, the assessors, and the audience, all bareheaded, their hands uncovered, and unarmed, signifying that they would cover no right with unright, that they would do nothing underhand, and that they were at peace with the emperor and the law. They wore short mantles to show that as the cloak covers the body so should their love cover justice. Each party was entitled to produce compurgators, and the verdict was left to the assessors. An appeal, however, lay, if claimed before the court broke up, to the Secret Closed Tribunal of the Imperial Chambers, which usually held its sittings at Dortmund. These proceedings were for the uninitiated; for the initiated it was sufficient that the accused, laying his two forefingers on the naked sword, swore he was innocent; but one of the initiated convicted of revealing the secrets of the tribunal was immediately hung. When the sentence was pronounced, the execution of which, in case of capital punishment, was intrusted to all the members of the order, the condemned, if present, was at once executed; if he had not appeared, the schöppen were set in pursuit of him. Whenever three schöppen (for that was the number necessary for an ordinary execution) met the person condemned, they seized him, and with one of the ropes which they carried in their sleeves, hung him on the next tree, fixing a dagger in the trunk to denote that the deceased was killed by the holy tribunal. When such an event occurred, no court of law dared to take notice of the affair; every man's tongue was struck silent, for fear of incurring the vengeance of this terrible body. This punishment, however, was seldom inflicted upon those who readily appeared; in such cases the judges were satisfied with causing the defender to redress the wrong that he had inflicted. But if the accused failed to attend the summons, which was repeated three times, judgment passed by default, and the accused was declared an outlaw. Every schöppe, though he were the father or son of the criminal, was in duty bound to put him to death by the rope, the dagger, the sword, or even poison, and to revenge any insult offered to the tribunal upon man, woman, or child, noble or plebeian, freeborn or slave, house or farm, monastery or nunnery, that dared to shelter him.

The power of this tribunal was greater than that of the Holy Inquisition; it struck terror into all Germany, and especially in Westphalia, where it originated. Princes and nobles were anxious to enter into this order either for protection against their enemies, or to avoid the jurisdiction of a tribunal the power of which they were unable to withstand. Towards the end of the 15th century, the German empire having acquired more political consistency, and the objects for which this tribunal was instituted having ceased to exist, it gradually lost its power, without being abolished by any legislative enactment. Some traces of the revival of this tribunal appear in the 17th century, but its efforts to regain its former importance were checked by the public authorities. It sunk at length into utter insignificance; and a remnant of it which continued to act as a kind of society for the suppression of vice was abolished in Westphalia by order of Jerome Bonaparte in the year 1811. The members of the order maintained that they were the true and genuine possessors of the secrets intrusted to the Fehm by Charlemagne, but no one would or could explain the signification of the mystical S.S.G.G. Goethe has given a graphic picture of the working of this tribunal in his historical drama 'Göetz von Berlichingen;' and Scott in his 'Anne of Geierstein,' has described the proceedings of the tribunal: but neither have confined themselves to the historical facts, and the last has wandered widely. The best historical accounts of its organisation are by Bork, 'Geschichte der Westphalischen Vehmgerichte,' Bremen, 1815; Paul Wigand, 'Das Femgericht Westfalens,' Hamm., 1827; and Usener, 'Die Frei und heimlichen Gerichte Westphalens,' Frankfurt, 1832.

FEIGNED DISEASES. There are few subjects attended with more difficulty than the detection of feigned diseases, especially when they are the result of a system which permits of a constant refinement of the deceit by practice. This has been especially the case in France, where the object has been to escape the conscription. Foderé has observed, "that it was brought to such a perfection as to render it as difficult to detect a feigned disease as to cure a real one." The motives which usually lead to this practice are—1, A release from obligation. This is frequently the case in the army and navy, where the men will pretend to be ill to escape duty or to gain their discharge. In this form it has got the name of *Malingering.* Beggars, too, often feign illness when they are offered work, preferring the easy task of soliciting charity to the labour of an occupation. 2, The hope of gain. This motive comes into operation where the object is to obtain relief from the parish, to impose upon the benevolence of private persons, to procure the allowances of benefit societies, clubs, &c., to get admitted into an hospital, or to obtain compensation for some pretended injury. 3, To procure release from confinement or an exemption from punishment. This motive is a source of deceit with boys and girls at school, persons committed to prison, &c. To these may be added the love of exciting the sympathy or gaining the attention of others, where no hope or need of gain exists. This motive acts in all classes of society, and leads individuals of otherwise the highest moral character to imitate all forms of disease. It is observed most frequently in young and unmarried females, and is frequently carried to the extent of feigning diseases for which capital operations are required; and instances are not wanting where surgeons (not much however to their credit) have removed legs, breasts, and arms at the solicitation of such patients.

There is no natural limit to diseases which may be feigned; but some being much more easily imitated than others, and less easily detected, are most frequently assumed. Feigned diseases may be divided into, 1, those which are obvious to the senses; 2, those depending upon the description of the impostor, and 3, those of a complicated nature, presenting symptoms of both kinds. Amongst diseases obvious to the senses are an increased or diminished size of parts, wounds, malformations, ulcers, discharges, spasmodic and paralytic affections. A favourite mode of increasing the size of parts, and producing tumours, is by injecting air beneath the cellular membrane. In this way such diseases as dropsy, local and general, hernia, hydrocele, varicose veins, elephantiasis, œdema of the extremities, may be simulated. Pressure also, by means of ligatures, &c. on the veins, will produce swellings of parts of the body. Swellings also of the joints, so as to resemble white swellings, are produced by the application of various acrid plants, as the ranunculus acris and sceleratus to the part. Polypi, hydatids, malignant tumours, and hæmorrhoids, are imitated by affixing in some manner the intestines and other viscera of animals to the parts of the body in which these diseases occur. Cancer has been imitated by a cow's spleen, and by a sponge moistened with milk fixed under the arm-pit. The various malformations of the body are feigned by obstinate and long-continued flexion of the part, aided by inaction and the use of tight bandages. Sometimes these contractions are accompanied by a wound, in order to prove that they have been effected by a burn. Many means have been proposed for detecting this class of impositions, such as compressing with a tourniquet the nerves that supply the contracted muscles; applying a wet bandage tightly round the limb, so that when it becomes dry it may overcome the contraction; moving the contracted limb during natural sleep or that produced by narcotics; or making extension whilst the person is under the influence of an emetic, or when his attention is directed to other objects; recommending the coast of Africa, or some other disagreeable thing, as a cure. Wounds and sores are produced in a variety of ways. Wounds, when self-inflicted, will always be in positions where persons can get at the spot where they exist, with their own hands. Accomplices are however sometimes engaged even in this. Ulcers are among the most common of feigned diseases. They are produced by red-hot iron, by caustics, as corrosive acids and alkalies, and the juices of various plants, as of the ranunculus acris and sceleratus, the spurge-laurel, the euphorbium, arum maculatum, and juniper. Where persons are suspected of keeping up ulcers in their legs by irritants, the placing their legs in a box and locking them up will allow the ulcers to heal. The various forms of cutaneous disease are produced by the application of irritants to the skin, as pounded garlic, euphorbium, cantharides, gunpowder, nitric acid, bay salt, &c. The discoloration of jaundice is imitated by various dyes, as well as the appearance of bruises. Ophthalmia is a disease often feigned, and is commonly produced by the application of irritants, as snuff, pepper, tobacco, blue vitriol, salt, alum, &c. The progress of the inflammation in these cases is usually more rapid than in the idiopathic form. It is mostly also confined to one eye, for obvious reasons; and when occurring in the army it may be suspected, if epidemic, when it only comes on in privates and non-commissioned officers. Diseased discharges are often simulated. Vomiting is effected by pressing on the pit of the stomach, by swallowing air, by strong and sudden action of the abdominal muscles, by tickling the fauces, and the use of emetics. Diarrhœa and dysentery are produced by taking drastic purgatives. Fragments of brick, slate, small pebbles, pieces of quartz, and flint, have been introduced into the urethra, to bear out the alleged existence of urinary calculus. Hæmaturia has been simulated by tinging the urine with various colouring matters, and the disease has really been brought on by the taking of savin, cantharides, and turpentine. Spitting of blood is a favourite assumed disease. It is simulated by placing a sponge in the mouth filled with bullock's blood, by cutting the mouth and gums, and by sucking blood from other parts of the body. A vomiting of urine and fæces have taken place by the stealthy introduction of the contents of the bladder and rectum into the stomach.

The spasmodic diseases to which the system is subject have been imitated with great success, and none more so than epilepsy. It has for its peculiar recommendation, that the person who is subject to it may be well at intervals and assume the attacks when it best suits him. The best criterion of imposition is the want of the total insensibility which characterises the true fits. In the feigned disease the application of stimulants will seldom fail to elicit indications of sensibility. Hartshorn or burning sulphur may be introduced under the nose: alcohol and turpentine may be dropped into the eye, and mustard or common salt placed in the mouth. Pricking the skin with sharp-pointed instruments has also been recommended. This however is frequently resisted. Dr. Guy recommends "flecking" the feet with a wet towel. He says he has by this means aroused a patient from a mesmeric slumber when all other mechanical stimulants and cold affusions had failed. Convulsions are often imitated; but where they are fictitious they cannot be sustained for any length of time without great exhaustion. Chorea is also often imitated. Electricity and cold affusions are the best remedies for this disease, and are likely to be effectual in the case of impostors. Hysteria, catalepsy, tetanus, hydrophobia, some forms of tonic spasm, stammering, strabismus, and difficulty of swallowing, are other diseases of the nervous system which are often imitated. Paralytic affections are also frequently simulated. The treatment resorted to for the cure of these diseases, when natural, would be found a trying ordeal for most impostors. Cases however are related in which impostors have resisted the most active treatment; and a case of simulated lethargy is on record, in which an individual resisted with only a single groan the operation of trephining.

Another class of feigned diseases are those which depend chiefly upon the description given by the impostor. These are all embraced in increased and diminished sensations. Increased pain of one or many organs is commonly feigned. It is easily assumed but not easily detected, as many pains, such as that of tic douloureux, come on in an apparently healthy state of the system; and many pains of a severe character are dependent on exceedingly obscure causes. There are no rules which can be laid down for the detection of simulated pain; and it is only those who have extensively observed the effects of real pain on the system, that can readily distinguish that which is pretended. Of diminished sensations, blindness, and deafness are those most frequently feigned. Amaurosis may be really produced for a time by the application of belladonna, henbane, spurge laurel, and tobacco; but under these circumstances it disappears when the impostor is carefully watched. Deafness is often assumed, but it may be detected by unexpectedly or sharply calling out the name of the individual, by calling him by name when asleep, or letting a piece of money fall close to him. Dumbness has been successfully feigned, and cases are recorded which resisted every attempt at discovery. It may be frequently detected by giving the person a sudden and unexpected knock, or a prick with a pin.

Sometimes general diseases are assumed, embracing a collection of symptoms. Of these, the most frequently assumed are fever, ague, rheumatism, phthisis, asthma, dyspepsia, jaundice, inflammations of the bowels, stomach, and kidneys. These feigned diseases are only to be detected by a knowledge of the real diseases, when a correct diagnosis is not often difficult. Of diseases involving complicated symptoms, that of unsoundness of mind is most frequently and most successfully feigned. The success however does not depend so much on the ease with which the symptoms of true insanity are imitated, as upon the ignorance that prevails of the distinguishing characters of real insanity. When these are once known an impostor may be easily detected. The most frequent form of assumed madness is general mania. In addition to the characters of the true disease, special tests have been proposed, such as the use of the whirling chair, and "repeating to the suspected person a series of ideas recently uttered, when the real maniac will introduce new ideas; the impostor, on the contrary, will deem it expedient to repeat the same words." (Guy.)

The following general rules for detecting feigned diseases have been given by Zacchias :—

1. The first is, that the physician must in all suspected cases inquire of the relatives and friends of the suspected individual what are his physical and moral habits. He must ascertain the state of his affairs, and inquire what may possibly be the motive for feigning disease, particularly whether he is not in immediate danger of some punishment from which this sickness may excuse him.

2. Compare the disease under examination with the causes capable of producing it—such as the age, temperament, and mode of life of the patient. Thus artifice might be suspected if a person in high health and correct in his diet should suddenly fall into dropsy or cachexia; and again if insanity should suddenly supervene without any of its premonitory symptoms. It is contrary to experience to find such diseases occur without some previous indications.

3. The third rule is derived from the aversion of persons feigning disease to take proper remedies. This indeed will occur in real sickness, but it rarely happens when severe pain is present. Anything that promises relief is generally acceptable in such cases; those on the contrary who feign delay the use of means.

4. Particular attention should be paid to the symptoms present, and whether they necessarily belong to the disease. An expert physician may thus cause a patient to fall into contradiction, and lead him to a statement which is incompatible with the nature of the complaint. To effect this it is necessary to visit him frequently and unexpectedly.

5. The last direction is to follow the course of the complaint and attend to the circumstances which successively occur.

(Beck, *Medical Jurisprudence*; Thomson, A. T., *Lectures on Medical Jurisprudence*; Guy, W. A., *Principles of Forensic Medicine*.)

FELLOWSHIP, in books of arithmetic, the rule by which profit or loss is divided among those who are to bear it, in proportion to their investments or interests in the transaction. It is usual to divide this rule into two parts, of which the first supposes all the investments to have been made for the same time, and the second supposes the partners to have employed their money during different times. One simple case of each will be sufficient.

Question 1. A, B, and C embarked 10l., 9l., and 8l. in a venture which yielded 30l. of profit. How much belongs to each?

If 10 + 9 + 8, or 27 adventurers embarked 1l. each, it is clear that each of them should have the 27th part of 30l. Let 10 of them assign their shares to A, 9 to B, and 8 to C, and we have the case in question. That is, A should have 10-27ths, B 9-27ths, and C 8-27ths of the whole profit.

Question 2. A profit of 30l. was realised by A embarking 10l. for two months, B embarking 9l. for three months, and C embarking 8l. for four months. How much ought each to gain?

Here the 1l. of A and the 1l. of B are differently circumstanced: the second was employed half as long again as the first, and consequently should gain half as much again. Now let *one pound sterling employed during one month* be called a share: then A invested 20 shares, B 27 shares, and C 32 shares. Hence, as before, 20 + 27 + 32 being 79, A should have 20-79ths, B should have 27-79ths, and C 32-79ths of the gain.

The first is a rule of very frequent occurrence; but the second is rare, for it seldom happens that money is withdrawn from an undertaking, except upon some specific agreement. But the modern practice of dividing an enterprise into shares of equal amount, and never subdividing a share, reduces all questions of fellowship to simple division. But, as often happens, a name has got into the wrong place. The result which division gives to A, instead of being called his *quotient*, is called his *dividend*.

FELLOWSHIP (in a college) is an establishment in the college entitling the holder to a share in its revenues. The fellows are a part of the corporation. [College.] Fellowships are either original, that is, part of the foundation or scheme of the original founder; or ingrafted, that is, endowed by subsequent benefactors of a college already established. Where the number of fellows is limited by the original foundation, new fellows cannot be made members of the corporate body without a new incorporation. If the number is not limited by the charter, it seems that the corporation may admit new fellows as members, who will be subject to the statutes of the original foundation in all respects. Graduates of each several college are in general only eligible to fill a vacant fellowship in the establishment to which they belong after having been elected to scholarships on the foundation, awarded at examinations held by the master and fellows in being. But in some cases special rules which control the election prevail, as where the fellow must be of the blood of the founder, or where he must be a native of a particular county, &c., and in some few cases fellowships are open to the graduates of several colleges, or even the whole university. In Downing College graduates of both universities are eligible. These rules are prescribed by the founder, modified in some cases by the bye-laws of the several colleges. Some few fellowships may be held by laymen, but in general they can be retained only by persons already in holy orders, or who are ordained within a specified time. Fellowships are of unequal value, varying from 30l. and less to 250l. a year and upwards, the senior fellowships in those colleges where there is any such distinction between the fellows being the most lucrative; but all confer upon their holders the right to apartments in the college, for which in some instances a small annual sum is charged as rent, and certain money privileges as to commons or meals. They are in general tenable for life, unless the holder marries, or inherits estates which afford a larger revenue, or accepts one of the livings belonging to the college which cannot be held with a fellowship; but in the new statutes now under discussion, the commissioners for the University of Cambridge propose to limit the tenure in some of the colleges (at the same time removing the restriction against celibacy). These livings are conferred upon the fellows, who in general have the option of taking them in order of seniority, though in some colleges the holders of particular offices have priority of choice, as for instance in Trinity College, Cambridge, where the vice-master has such right by a bye-law of the college.

The whole subject of fellowships in the different colleges of the University of Cambridge is at the present time, January, 1860, in a transition state; the commissioners above-mentioned being engaged in the duty of revising and altering the old statutes, in which revision very important changes both as to the tenure of, and mode of election to, fellowships, and the position of the fellows themselves, are contemplated.

FELO-DE-SE (a felon of himself) is a person who, being of sound mind and of the age of discretion, deliberately causes his own death; and also, in some cases, where one maliciously attempts to kill another, and, in pursuance of such attempt, unwillingly kills himself, he is adjudged a felo-de-se. (1 Hawk. P. C. c. 27, § 4.) When the deceased is found by the coroner a felo-de-se, all his chattels, real and personal, are forfeited to the crown, though they are usually restored upon payment of moderate fees; and therefore a will made by him is void as to his personal estate, though not as to his real estate, nor is his wife barred of her dower. Formerly he was buried in the highway with a stake driven through his body. These laws, so highly repugnant to the feelings of humanity, being a punishment to the surviving relatives of the deceased, in addition to the general impression that no man in his sound sense ever does commit suicide, caused juries in general to find that the deceased was not of sound mind; and by the Act 4 Geo. IV. c. 52, the legislature has so far yielded to the popular and herein the better opinion, as to abolish the former ignominious mode of burial, and to provide that a felo-de-se shall be privately interred at night in the burial-ground in which his remains might by law have been interred if the verdict of felo-de-se had not been found against him.

FELONY, in the general acceptation of the English law, comprises every species of crime which occasioned at common law the forfeiture of lands or goods, or both, and to which a capital or other punishment might be superadded, according to the degree of guilt. Various derivations of the word have been suggested. Sir Henry Spelman supposes that it may have come from the Teutonic or German "fee" (fief or feud) and "lon" (price or value), or from the Saxon "feelen" (to fall or offend). Capital punishment by no means enters into the true idea and definition of felony; but the common notion of felony has been so generally connected with that of capital punishment, that law-writers have found it difficult to separate them: indeed, this notion acquired such force, that if a statute made any new offence felony, the law implied that it should be punished with death. The number of offences, however, to which this punishment is affixed by the law of England is now very small: and several statutes were passed early in the present reign (1 Vict.) founded upon the principle that the punishment of death should only be inflicted for crimes accompanied with violence. Thus c. 84 substituted the punishment of transportation for that of death in those cases where the latter might still be inflicted for forgery; c. 85 materially lessened the severity of the punishment of offences against the person; c. 86 enacted that burglary unaccompanied with violence shall no longer be punished capitally, and provided that, so far as the offence of burglary is concerned, the night should be considered to commence at nine in the evening and to conclude at six in the morning; c. 87 mitigated the punishment attending the crimes of robbery and stealing from the person; c. 88 rendered piracy punishable with death only when murder was attempted; c. 89 regulated the punishment for the crime of arson; c. 90 mitigated the punishment of transportation for life in certain cases; and c. 91 abolished the punishment of death in the cases there specified. The principle of amelioration was carried still further four years later by the stat. 4 & 5 Vict. c. 56, abolishing capital punishment for embezzlement by servants of the Bank of England, offences under the Stamp Act, riotous demolition of churches, houses, &c., and also for rape. Great numbers of offences were formerly liable to this severe punishment; and it must seem strange to persons who do not observe the extreme difficulty with which old established customs and prejudices, however ill founded, are subverted, that this system should so long and so obstinately have withstood the most convincing arguments and conclusive statistical evidence. It is impossible, within the limits of this article, to enumerate the crimes which the law considers to be felonies; and the more so, as the word felony has long been used to signify the degree of crime rather than the penal consequences. It may be sufficient, therefore, to state generally, that murder, manslaughter, felo-de-se, robbery, arson, burglary, some offences against the coin, &c., are considered and classed as felonies; and (the distinction between grand and petit larceny no longer existing) every larceny is a felony.

Besides the special punishment affixed to his crime by the law, a felon upon conviction forfeited the rents and profits of his lands of inheritance during his life to the king (which are now usually compounded for), and also all his goods and chattels absolutely; and as attainder of felony caused corruption of blood, his lands, except of gavelkind tenure, escheated to the lord of the fee. This last consequence, however, was taken away by stat. 54 Geo. III. c. 145, which enacted that, except for treason or murder, corruption of blood should not follow attainder; and as difficulties might sometimes occur in tracing descent through an ancestor who had been attainted, it was, by the 3 & 4 Will. IV. c. 106, § 10, enacted that descent may be traced through any person who shall have been attainted before such descent shall have taken place. [ESCHEAT; FORFEITURE.]

In connection with this subject, it may be interesting to refer to the distinction formerly taken between felony with and without benefit of clergy, as explained in the article BENEFIT OF CLERGY.

FELT; FELTING. Under HAT MANUFACTURE will be found a description of that peculiar process whereby woollen and fur fibres are felted into a material suitable for hats; but woollen fibres are also sometimes combined by the felting instead of the weaving process for carpets and various kinds of cloth. Among other manufacturing firms for the purpose, there is the 'Patent Felted Woollen cloth Company;' by whom is made felt carpets, embossed and printed felt table-covers, felt polishing cloth for plate and other purposes, felt for veterinary purposes, felt waistcoatings, felt coach-cloths and railway-carriage-linings, upholsterers' felt, and felt for pianofortes.

A material called *Asphalted Roofing Felt* has come rather extensively into use. The two principal kinds are Croggon's and McNeill's. The qualities of this material are imperviousness to rain and snow, non-conductibility of heat, elasticity, lightness, durability, economy, and easy application. The felt is used for roofing buildings; for lining granaries and stores; for protecting ceilings from damp; for lining the insides or outsides of wooden buildings; for covering conservatories and garden-frames; for thatching corn and hay ricks; and for many other purposes. This felt is sold in large sheets at the rate of about a penny per square foot. Another kind, called Inodorous Felt, is saturated with waterproof material free from the smell of the ordinary felt, and is used to prevent wall-paper from being injured by damp. There is also a patent Felted Sheathing, for covering ships' bottoms; it is a felted mixture of hair and vegetable fibre, not intended as a substitute for copper sheathing, but to be used as a layer beneath it. Another variety, the Non-conducting Felt, is used as a covering for boilers and steam-pipes, on account of its power of confining the heat within the vessel enclosed by it; it is used for fixed, locomotive, and marine steam-engines, and in breweries and distilleries: it is said also to be a good protective of water pipes from frost. An Asphalted Felt is made in long pieces, 32 inches wide by about 30 yards long, and is sold in any smaller or larger quantities. The fibrous material of which it is formed is saturated with asphalte or bitumen. Some of the sheds and other buildings at Devonport and Woolwich Dock Yards, the Isle of Portland, and elsewhere, have been covered with this material; but its inflammability is a disadvantage.

For all the above and for other kinds of uses, new felted materials have been patented within the last few years. Williams's patent for felting wool or fur or both into cloth, taken out in 1840, was extended for a further period in 1854, on the ground that the process, although involving a heavy expenditure, had not yet yielded much profit. Parker's felt, patented in 1851, is made in a peculiar way. The fibres of wool, fur, or hair, are first made into a batt or soft sheet by the action of carding and doffing engines; this batt is wound on a roller and conveyed to the felting machine. There are two strata or beds of bars of wood, laid crosswise on straps or belts; the beds are horizontal, and a little distance apart; the batt of fibres is brought between them; and all the bars of the upper bed, having a reciprocating vertical movement, felt the fibres while travelling onward. The roller and the two beds dip in water, to facilitate the process. In reference to the felt for retaining the heat of steam-boilers, we may state that a new mode of procedure was introduced by Mr. Garnett in 1858. The felt is here composed entirely of waste woollen refuse from paper-mills, converted to coarse pulp in the ordinary rag engines; it is put upon the steam boiler in a wet or pulpy state, and is felted or matted together by being beaten with pieces of flat wood. When dry, it becomes one solid piece. As a proof of its excellent qualities as a non-conductor of heat, it is asserted that on a boiler working at 50 or 60 tons pressure, candles may be laid on the felt for weeks together, without melting. The felt may at any time be taken off and replaced, by steeping in hot water till softened. So far as concerns the manufacture of felted cloth for garments, America appears to have made a greater advance than England. Mr. Whitworth, the eminent machinist, in reporting on the machines displayed at the Great Exhibition in New York in 1853, had occasion to notice the Bay State Mills at Lawrence, nine miles from Lowell, and twenty-six from Boston. This is one of the largest woollen mills in the world, employing more than 2000 hands. He said:—"The whole waste from the mills is worked up in the manufacture of felted cloth. The felt-making machine employs but a small space. A sliver of wool is taken from the carding machine and passed between two endless cloths; these carry it over a narrow steam-box, where it is steamed. It is then passed under a vibrating pressing-plate, which operation causes the fibres to curl and interlace with each other, and so form a cloth." The cloth thus made is of fair quality in fineness and elasticity. A new and useful fabric made in that establishment is felted lining-cloth, composed of a small quantity of wool felted upon gauze; the gauze forms a back to the felt; and the substance obtained by this means is much thicker than the small quantity of material employed would seem to denote. The gauze surface is hidden when the lining is applied to a garment, and the felt is quite strong enough for the purpose in view. Some of the carpet and cloth felt made at these mills is printed by block-work; and in a few instances cloth for coatings is printed of two different colours on the two surfaces.

FEME-SOLE. [WIFE.]

FEMININE. [GENDER.]

FENCES are necessary wherever cattle are depastured and properties divided; and according as they are intended to prevent men or cattle from trespassing over them, they are formed of various materials and dimensions.

When a park is enclosed to keep in deer or game, the best fence is a stone or brick wall, well built with lime-mortar; but as this is expensive where stone and lime are not at hand, the common *park-paling* is more frequently met with. This is composed of posts and rails of oak mortised and pinned together, and split pales of the same material nailed upon these in an upright position. The pales are split out of the trunks of oaks, where there are no branches or knots, when the sap is still in them. They are about half an inch thick, and with feather edges, that is, diminishing in thickness from one side to the other: their usual width is five inches. When they are nailed on the rails, which are usually of a triangular form, the thickest edge of one pale is nailed over the thinner edge of the preceding, forming thus a very close fence. Every alternate pale is placed three or four inches higher than its neighbour, which gives the top of the fence a castellated form. This is not done merely for appearance; but it makes it more difficult to climb over, and the deer are not so apt to leap at it as if the top were a straight line. The distance between the posts is usually nine feet; and the three rails with the pales nailed on them is called a panel, and may be conveniently moved at once when any alteration in the fence is required. A whole fence may be moved at a small expense, merely by digging out the posts, and placing them elsewhere. The panels come in regularly, and are pinned into the old mortices in the posts. Sometimes the pales are nailed at a distance from each other, which makes the *open-paled fence*, and the pales are then generally cut to a point at top. This fence is peculiar to Great Britain and Ireland, and is very seldom found on the Continent.

In the Jura and the Alps, where wood abounds, a rough fence is frequently made with strong split pieces of wood, which are fixed obliquely in the ground and supported at the upper end by two others placed in the form of a cross. It is not a very strong fence, but it is sufficient to prevent the cows from straying, for unless a bull with his horns makes a gap in it, they will not attempt to pass it.

In wild mountain pastures in Scotland and Ireland, it is usual to separate the properties of different individuals or that of parishes by rough stone walls put together without any mortar. The materials are generally at hand, and a rough and efficient fence is made without much labour.

Some of these walls are built with considerable skill and are very durable; especially if the stone is of a nature to split with a flat surface, in which case a dry wall may be built which has all the appearance of one built with mortar. Sometimes a layer of mortar is laid on the stones at a little distance from the ground, and another near the top. The coping is usually made of flat stones, which are sometimes placed on edge in a direction across the wall, and wedged together along the top of it or set in mortar, forming a very rough coping, which it is not easy to get over.

Where stones are not at hand, or less trouble is taken, a high bank of earth faced with sods of grass is substituted for a wall. This is not so durable and is more easily surmounted, unless a hedge of some kind be planted along the top. Furze seed is often sown for this purpose, and soon forms an excellent fence, which by proper care and clipping will last a long time. But the most common kind of fence for fields is the hedge and ditch, the bank being raised with the earth and sods taken out of the ditch, and the hedge planted on the side of the bank towards the ditch or on the top. Sometimes there is a ditch on both sides. In flat wet lands this last is extremely useful, not only as a fence, but as a drain for the superfluous water. When the ditch is intended to carry off the water, and there is only one, it is of consequence that it should be so placed as to answer this purpose effectually; it should therefore always be on that side of the bank where the ground rises, for otherwise the bank will impede the natural flow of the water, and it will be necessary to cut through it in different places to let the water running from above have an outlet into the ditch. In some extensive inclosures of land great inconvenience has arisen from the neglect of the surveyor in not attending to this circumstance, and setting out the bank on the upper side. Where they are not required as drains, it is a great waste of land to have any ditches, and a simple hedge planted on the surface of the soil is much to be preferred. Of all fences, a live hedge, which is carefully planted, and kept properly cut and trimmed when it is grown up, is by far the best. [Hedge.]

When a fence is required within sight of a dwelling, and it is desirable for it to be concealed, a deep ditch is sometimes dug, and a fence placed in the bottom of it at such a depth as not to appear above the level of the ground. This is called a *sunk fence*. Sometimes a wall is built against a perpendicular side of a ditch, and some very light fence is placed obliquely outwards near the top of it and level with the ground. When it is desired to keep off sheep or cattle from a lawn or pleasure-ground without obstructing the view of the park or the fields, this "ha ha" fence is very useful. A variety of *light fences of iron* have been invented for the same purpose: some of these are fixed and others moveable; some have upright pieces of cast-iron as posts let into oak blocks sunk in the ground, and rods of wrought-iron passing through holes in the uprights; some have wire for the same purpose. But the most common iron fence is composed of separate wrought-iron hurdles which may be moved at pleasure, and are kept together by screwed pins and nuts. They are merely stuck into the ground, for which purpose they have the ends of the uprights sharpened and bent so as to form a foot. By having this bend alternately on the right and on the left, they form a very firm basis when two hurdles are joined, the left foot of the one being strengthened by the right foot of the other. A very neat fence may be made at a small expense by using as posts pieces of young larch-trees four or five inches in diameter, with the bark on, and passing iron rods through holes bored in them at certain distances from each other. A fence of this kind five feet high, with five horizontal rods five-eighths of an inch in diameter, is an excellent protection against cattle, and takes up no ground.

The greatest objection to the ditch and bank fence is that it takes up so much room. If the ditch is three feet wide, the bank will be the same. There is a foot along the ditch, and another along the bank, where the plough cannot reach; there are therefore eight feet lost. If the fields are squares of ten acres each, which is a convenient size, each field will have 1320 feet of fence in length, taking up 10,560 square feet of land, which is nearly a quarter of an acre. If to this be added the outer fences against roads, woods, or commons, it will be found that nearly one acre in twenty-five is taken up by banks and ditches. It is therefore a great saving to have a simple hedge without any ditch, wherever the land is well drained or has a porous subsoil.

It is usual in England to plant trees in the hedge-rows; and it is owing to this practice that England presents such a rich garden-like appearance, wherever there is a hill which enables one to see any extent of country. But trees are a great detriment to the farmer; and where the land is highly manured, the trees draw off much of the rich juices. The prudent tenant considers this in the rent; and although the landlord may now and then sell some timber, he pays dear for it in general by the annual deduction from his income on their account. Stone walls have a dreary appearance to the eye, but they are excellent fences; they take up little ground, they draw nothing out of the soil, they harbour no birds, and they are the best shelter against cold winds in spring. In an agricultural point of view, therefore, walls are to be preferred, unless the soil be favourable to the growth of the whitethorn or the holly; for clipped hedges are kept up at a much smaller expense than walls, and where there is no ditch, hedges take up as little room.

When hedges are preferred, whether with or without a bank and ditch, they must be protected until they are of a certain age; and for this purpose there are particular kinds of fences. When there is a bank and double ditch, and the hedge is planted on the top of the bank, which makes by far the most efficient fence, there are usually two fences, one on each side of the bank. These fences are made of rough posts and rails mortised into the posts. The posts are a foot or 18 inches in the ground, and 2 feet 6 inches out. They are placed in the side of the bank, inclined somewhat outwards, about 4 feet 6 inches asunder. The two rails are let into mortices in the alternate posts, and nailed to the middle post, which is rather slighter. Thus a very formidable fence is made, which those who follow the diversion of hunting, and are not very well mounted, dread to encounter. If there is only a single ditch, it is usual to plant the hedge in the side of the bank a little above the level of the ground. To protect the young thorns from being cropped by the cattle, it is usual to make a dead hedge of stakes with bushes and brambles interwoven on the top of the bank: and if there is pasture land on the side where the ditch is, a post and rail fence is put up along the edge of the ditch till the hedge is grown sufficiently not to be injured by the cattle. When branches of thorns and bushes only are used without stakes, it is called a *foot hedge;* when the branches are interwoven, and the top of the hedge is finished with rods wattled in, it is called a *stake and edder hedge*. Wherever neatness and durability are consulted, the stake and edder hedge is always preferred.

Besides these common fences, there are various others of a light or temporary nature, which are chiefly used in gardens and pleasure-grounds, and also when sheep only are to be kept out, or when a new quick hedge along an orchard or garden has been planted. A cheap and neat fence of this kind is made with stakes only planted in the ground, forming a series of St. Andrew's crosses: or with osier or hazel rods worked between stakes like basket-work, either horizontally and lightly or obliquely and closely. When the rods are split, the appearance is still neater and lighter. A variety of light iron fences made of slender rods or wire have been invented to protect flower-gardens or shrubberies from the depredations of hares and rabbits, and their forms differ according to the fancy and taste of individuals.

FEOD. [Feudal System.]

FEOFFMENT (in law) is that mode of conveyance of lands or real hereditaments in possession where the land passes by force of livery in deed, that is, actual delivery of a portion of the land, as a twig or a turf; or where the parties being on the land the feoffor expressly gives it to the feoffee, &c.; or livery in law or within view, that is, where the parties being within sight of the land, the feoffor refers to it and gives it to the feoffee. A feoffment was the earliest mode of conveying real hereditaments in possession known to the common law. A grant [Deed; Grant] was the mode used when lands subject to an existing estate of freehold, and when rents or other incorporeal hereditaments incapable from their nature of being the subjects of livery, were transferred. The term feoffment is evidently of feudal origin, its latinised form being feoffamentum, from feudare or infeudare, to infeoff, to give a feud. The mode of conveyance is however of much higher antiquity than the feudal system, the mode of transferring property by the delivery of possession being common to all nations in rude ages. (Gilb. 'Ten.' 386.) It prevailed amongst the Anglo-Saxons, who gave possession by the delivery of a twig or a turf, a mode still used in the admission of tenants of copyhold lands. The form of an ancient feoffment was singularly concise. There is a copy of one in the Appendix to the 2nd vol. of Blackstone's 'Commentaries,' No. 1.

Feoffments are now little used. The statute 8 & 9 Vict. c. 106, gave the last blow to a mode of conveyance already nearly obsolete. By this Act corporeal hereditaments are made to lie *in grant* as well as *in livery*. Thus actual or symbolical livery of seisin is unnecessary. See Blackst. 'Comm.' vol. ii. p. 311, Mr. Kerr's Ed.

The essential part of this mode of conveyance is the delivery of possession, or, as it is technically called, livery of seisin. In former times land was frequently conveyed without any deed or writing, by simple delivery. Subsequently it became the custom to have a written instrument called the charter or deed of feoffment [Charter], which declared the intention of the parties to the conveyance. But now, since the Statute of Frauds (29 Car. II. § 3), a written instrument is necessary.

Livery of seisin was at first performed in the presence of the freeholders of the neighbourhood, vassals of the feudal lord; because any dispute relating to the freehold was decided before them as pares curiæ, "equals of the court," of the lord of the fee. But afterwards, upon the decay of the feudal system, the livery was made in the presence of any witnesses; and where a deed was used, the livery was attested by those who were present at it.

Livery in deed may be made by the feoffor or his attorney to the feoffee or his attorney. When lands lie in several counties, as many liveries are necessary; and where lands are out on lease, there must be as many liveries as there are tenants, for no livery can be made but by the consent of the tenant in possession, and the consent of one will not bind the rest. But livery in law or within view can only be given and taken by the parties themselves, though lands in several counties may pass if they all be within view. Livery of this nature requires to be perfected by subsequent entry in the lifetime of the feoffor. Formerly, if the feoffee durst not enter for fear of his life or bodily harm, his claim, made yearly in the form prescribed by law, and called continual claim, would preserve his right. The security of property consequent upon the progress of civilisation having rendered this exception unnecessary, it was abolished by the Statute of Limitations, 3 & 4 Will. IV., c. 27, § 11.

Since the Statute of Uses [Bargain; Sale; Uses] introduced a more convenient mode of conveyance, feoffments have been rarely used in practice, and then rather for their supposed peculiar effects, as wrongful conveyances [Conveyances], than as simple means of transferring property. It has been usual to make corporations convey their own estates by feoffment, in consequence of the supposition that a corporate body cannot stand seised to a use, though it seems that this doctrine only applies to the case of lands being conveyed to a corporation to the use of others. (Gilb. 'On Uses,' Sugd. Ed. 7 note.) Where the object to be attained was the destruction of contingent remainders or the discontinuance of an estate tail, or the acquirement of a fee for the purpose of levying a fine [Fine] or suffering a recovery [Recovery], a feoffment was usually employed. Such indeed was the efficacy attributed to this mode of conveyance by the earlier law writers, that where the feoffor was in possession, however unfounded his title might be, yet his feoffment passed a fee; voidable, it is true, by the rightful owner, but which by the lapse of time might become good even as against him. Being thus supposed to operate as a disseisin to the rightful owner, it was thought till recently that a person entitled to a term of years might by making a feoffment to a stranger pass a fee to him, and then by levying a fine acquire a title by non-claim. This doctrine led to very considerable discussion, and though strictly accordant to the principle of the old law, yet being alike repugnant to the principles of justice and of common sense, it has been overruled.

In the progress of the discussion which ended in overturning the doctrine, arguments against its justice and expediency were used, rather than those founded upon the principles of law, and the bench even resorted to ridicule. Mr. Baron Graham in one case observed, "Yet is this pretended possession of paper and packthread to be called by the tremendous name of disseisin." The recent statute above-mentioned declares that a feoffment shall not have a tortious or wrongful effect, and thus most of the above learning has become mere antiquarianism.

The owner of lands of gavelkind tenure [GAVELKIND] may convey them by feoffment at the age of 15; and therefore in such cases, which are necessarily rare, a feoffment is still resorted to. It was also till lately frequently used for the sake of economy upon small purchases, in order to save the expense of a second deed, which was necessary where the conveyance was by lease and release.

FERMENT. Amongst organic compounds there exist a number of substances, some of animal others of vegetable origin, containing nitrogen, and in which the different constituents are held together by affinities so feeble, as to render them liable to spontaneous changes when exposed to favourable conditions, such as air, moisture, and warmth. Albumen, fibrin, casein, and gluten, for instance, are bodies of this class, which, when removed from vital influence, are exceedingly prone to enter into slow chemical decomposition, the final products of which are usually carbonic acid, water, and ammonia. Such substances during their passage through these chemical changes are termed *ferments*, and are capable of inducing, by mere contact with other bodies of more stable character, certain chemical changes. This operation of inducing chemical change by contact with a ferment is denominated *fermentation*, and is frequently employed both in chemistry and the arts for producing various interesting transformations. It is thus that alcohol is produced from sugar by the ferment yeast; the peculiar oil to which mustard owes its origin is generated by a similar reaction; and recently Berthellot has succeeded in transforming glycerin into grape-sugar by mere contact with a small fragment of animal membrane. As a ferment is essentially a body in a state of chemical change, it follows that the exact composition of such bodies is difficult, if not impossible, to determine, and hence we are unacquainted with the formula of any ferment. The following are the best known ferments:—

1. *Yeast*, produced when a saccharine solution, containing nitrogenous matter, as white of egg, is exposed to the air at a temperature of about 80° Fahr. The yeast separates as a kind of scum or froth. It transforms sugar into alcohol and carbonic acid, malic acid into succinic, acetic, and carbonic acids, and tannic acid into gallic acid.

2. *Diastase.* This ferment exists in malted barley, and possesses the property of converting starch into dextrin and grape-sugar.

3. *Synaptase* or *Emulsin*, exists in almonds, and converts amygdalin into oil of bitter almonds (*hydride of benzoyl*), formic acid, hydrocyanic acid, and sugar. [AMYGDALIN.] It also converts salicin into sugar and saligenin. According to Thompson and Richardson, when synaptase is boiled with caustic baryta, it yields *emulsic acid*.

4. *Myrosin*, contained in mustard. In contact with water and myronic acid, which is also contained in mustard, it produces oil of mustard.

5. *Decaying cheese*, in contact with cane- or milk-sugar, transforms them first into lactic acid, and then, by further contact, converts this lactic acid into butyric acid, carbonic acid, and hydrogen. The latter transformation is sometimes termed the *butyric fermentation*.

It must be remarked that all these fermentive processes require the presence of water and moderate warmth. They are frequently, but not invariably, attended with the evolution of gases. In many fermentive processes, the ferment itself suffers very little change, although large quantities of the fermentescible substance may have undergone transformation. The ferment does not, therefore, combine with any of the products of transformation; it appears only to communicate, by contact with the fermentescible substance, an impulse to the molecules of the latter, which determines their splitting up into two or more new compounds.

Processes which are generally regarded as analogous to the above, but which are less understood, can be induced in the bodies of living animals; thus when morbific matter, the fluid of putrefying flesh, vaccine matter, &c., are brought into contact with circulating blood, the latter suffers remarkable changes, attended with the production of certain forms of disease; and it is also more than probable that gaseous ferments are amongst the conditions necessary for the production of most, if not all, infectious diseases, such as typhus, cholera, scarlatina, &c.

FERMENTATION. [FERMENT.]

FERRIC ACID. [IRON.]

FERRICYANIDES. *Ferridcyanides.* Salts of FERRIDCYANIC ACID.

FERRIDCYANIC ACID ($H_3C_{12}N_6Fe_2$), *Hydroferridcyanic acid.* An acid analogous to FERROCYANIC ACID, obtained in red crystals by suspending ferridcyanide of lead in water, and passing sulphuretted hydrogen through the mixture. [CYANOGEN.]

FERROCYANIC ACID (H_2FeCy_3), *Hydro-ferrocyanic Acid.* Discovered by Porret, and by him called *ferruretted chyazic acid.* He procured it from the decomposition of ferrocyanide of potassium by the action of tartaric acid, or from ferrocyanide of barium by means of sulphuric acid. According to Berzelius it is best prepared by diffusing recently precipitated ferrocyanide of copper or lead through water, and passing hydrosulphuric acid gas through the mixture; the sulphur precipitates the copper or lead in the state of sulphuret, while the hydrogen, uniting with the cyanogen and iron, forms ferrocyanic acid. Any excess of sulphuric acid is to be got rid of by adding ferrocyanide of the metal employed. The solution should be quickly filtered and evaporated in vacuo over sulphuric acid. A white residue is obtained which when dissolved in water is inodorous, sour, reddens litmus paper, decomposes the alkaline carbonates with effervescence, forms ferrocyanides with them, and exhibits other proofs of a strong acid. When exposed to spontaneous evaporation in a warm place, colourless radiating crystals are observed, which have the appearance of four-sided prisms. This acid is decomposed by long exposure to the air, Prussian blue being formed and precipitated; this is also produced by adding to it a persalt of iron.

The aqueous solution is also decomposed by boiling; and when submitted to destructive distillation it yields hydrocyanic acid, hydrocyanate, and carbonate of ammonia, and carburet of iron remains. [CYANOGEN.]

FERROCYANIDES. Salts of FERROCYANIC ACID.

FERRY, an exclusive privilege for the carriage of horses and men across a river or arm of the sea for reasonable toll. The owner of a ferry cannot suppress it and put up a bridge in its stead without a licence; but he is bound to keep it always in repair and readiness, with expert men, and reasonable toll, for neglect of which he is liable to be punished by indictment. And, therefore, if a ferry is erected so near to an ancient ferry as to draw away its custom, it is a nuisance to the owner of the old one, for which the law will give him remedy by action. The ferry is in respect of the landing-place, and not of the water; and in every ferry the land on both sides ought originally to have been in the same person, otherwise he could not have granted the ferry. As all existing ferries are of great antiquity, and generally connect roads abutting on either side of the water, the original unity of possession is now mere matter of curiosity. A ferry is considered for some purposes a common highway.

FESCENNINE VERSES were rude licentious verses sung by young men at weddings, and before the door of the nuptial chamber. This was a very ancient custom at Rome: the practice, and some of the verses themselves, are said to have been introduced from Fescennium, an old Etruscan town near the present site of Civita Castellana. Festus and others derive the name Fescennine from *fascinum*, a charm or evil influence, which was supposed to have the power of depriving persons of their physical strength, and which the Fescennine verses were intended to avert. Valetta, a Neapolitan lawyer and poet of the 18th century, has written a curious book on the "Fascino," or evil eye, the belief of which is still prevalent at Naples. The Fescennine verses were distinct from the epithalamia, which were more refined and regular compositions. [EPITHALAMIUM.] Horace (Epist. ii. 1) says that Fescennine verses were sung by the country-people at harvest-time; and the custom of dealing out licentious jokes upon each other and upon strangers passing by is still retained by the vintagers in various parts of Italy. The name of Fescennine was given in general to licentious and satirical epigrams. Octavianus is said to have written some of this character against Pollio, in the time of the Triumvirate.

FEUD. [FEUDAL SYSTEM.]

FEUDAL SYSTEM. In treating of this subject, we shall endeavour to present a concise and clear view of the principles of what is called the feudal system, to indicate the great stages of its history, especially in our own country, and to state briefly the leading considerations to be taken into account in forming an estimate of its influence on the civilisation of modern Europe.

The essential constituent and distinguishing characteristic of the species of estate called a feud or fief was from the first, and always continued to be, that it was not an estate of absolute and independent ownership. The ultimate property, or *dominium directum*, as it was called, remained in the grantor of the estate. The person to whom it was granted did not become its owner, but only its tenant or holder: he possessed the *dominium utile* only. There is no direct proof that fiefs were originally resumable at pleasure; but the position is laid down in almost every writer on the feudal system, and, if not to be made out by any decisive instances, it is at least strongly supported not only by general considerations of probability, but also by some indicative facts. The fief was certainly at one time revocable, at least on the death of the grantee. In receiving it, therefore, the grantee had received not an absolute gift, but only a loan, or at most an estate for his own life.

This being established as the true character of a primitive feud or fief, may perhaps throw some light upon the much disputed etymology and true meaning of the word. *Feudum* has been derived by some from a Latin, by others from a Teutonic root. The principal Latin origins proposed are *fœdus* (a treaty) and *fides* (faith). The supposition of the transformation of either of these into feudum seems unsupported by any proof. These derivations, in fact, are hardly better than another resolution of the puzzle that has been gravely offered,—namely, that feudum is a word made up of the initial letters of the words "fidelis ero ubique domino vero meo." The chief Teutonic etymologies proposed have been from the old German *faida*, the Danish *feide*, or the modern German *vehd*, all meaning battle-feud or dissension; but the most acceptable is from *fe* or *fee*, which it is said signifies wages or pay for service, the word *od* or *odh*, to which the signification of possession or property is assigned, being combined with it. Sir Francis Palgrave ('Rise and Progress of Engl. Com.,' pp. 204–207) doubts if the word *feudum* ever existed. The true word seems to be *ferdum*, or *feftum*. *Fiev* or *fief* (latinised into *ferodium*, which some contracted into *ferdum*, and others, by omitting the *v*, into *feudum*) he conceives to be *fitef*, or *phitef*, and that again to be a colloquial abbreviation of *emphyteusis*, pronounced *emphytefsis*, a well-known term of the Roman law for an estate granted to be held not absolutely, but with the ownership still in the grantor and the usufruct only in the hands of the grantee. It is certain that *emphyteusis* was used in the middle ages as synonymous with *precaria;* that *precariæ*, and also *præstitæ*, or *præstariæ* (literally loans), were the same with *beneficia ;* and that *beneficia* under the emperors were the same or near the same as *fiefs*. The word *feu*, which in Scotland means an estate held of a superior or lord, for which, as explained by Erskine ('Principles,' b. ii., tit. 4), a rent, or feu-duty, as it is called, is always paid, has "a strong resemblance to the Roman *emphyteusis*, in the nature of the right, the yearly duty payable by the vassal, the penalty in the case of not punctual payment, and the restraint frequently laid upon vassals not to alien without the superior's consent."

The origin of the system of feuds has been a fertile subject of speculation and dispute. If we merely seek for the existence of a kind of landed tenure resembling that of the fief in its essential principle, it is probable that such may be discovered in various ages and parts of the world. But feuds alone are not the feudal system; they are only one of the elements out of which that system grew. In its entireness, it is certain that the feudal system never subsisted anywhere before it arose in the middle ages in those parts of Europe in which the Germanic nations settled themselves after the subversion of the Roman empire.

Supposing feud to be the same word with the Roman emphyteusis, it does not follow that the Germanic nations borrowed the notion of this species of tenure from the Romans. It is perhaps more probable that it was the common form of tenure among them before their settlement in the Roman provinces. It is to be observed that the emphyteusis, the precaria, the beneficium, only subsisted under the Roman scheme of polity in particular instances, but they present themselves as the very genius of the Germanic scheme. What was only occasional under the one became general under the other. In other words, if the Romans had feuds, it was their Germanic conquerors who first established a system of feuds; upon their first settlement in the conquered provinces.

We know so little with certainty respecting the original institutions of the Germanic nations, that it is impossible to say how much they may have brought with them from their northern forests, or how much they may have borrowed from the imperial polity, of the other chief element which enters into the system of feudalism, the connection subsisting between the grantor and the grantee of the fief, the person having the property and the person having the usufruct, or, as they were respectively designated, the suzerain or lord, and the tenant or vassal. Tenant may be considered as the name given to the latter in reference to the particular nature of his right over the land as the *holder* of it, in short; vassal, that denoting the particular nature of his personal connection with his lord. The former has been already explained; the consideration of the latter introduces a new view. By some writers the feudal vassals have been derived from the *comites*, or officers of the Roman imperial household [COUNT]; by others from the *comites*, or companions, mentioned by Tacitus ('German.' 13, &c.) as attending upon each of the German chiefs in war. The latter opinion is ingeniously maintained by Montesquieu (xxx. 3). One fact appears to be certain, and is of some importance, namely, that the original vassali or vassi were merely noblemen who attached themselves to the court and to attendance upon the prince, without necessarily holding any landed estate or beneficium by royal grant. In this sense the words occur in the early part of the 9th century. Vassal has been derived from the Celtic *gwas*, and from the German *gesell*, which are probably the same word, and of both of which the original signification seems to be a helper, or subordinate associate, in labour of kind.

If the vassal was at first merely the associate of or attendant upon his lord, nothing could be more natural than that, when the latter came to have land to give away, he should most frequently bestow it upon his vassals, both as a reward for their past and a bond by which he might secure their future services. If the peculiar form of tenure constituting the fief did not exist before, here was the very case which would suggest it. At all events, nothing could be more perfectly adapted to the circumstances. The vassal was entitled to a recompense; at the same time it was not the interest of the prince to sever their connexion, and to allow him to become independent; probably that was as little the desire of the vassal himself; he was conveniently and appropriately rewarded therefore by a fief, that is, by a loan of land, the profits of which were left to him as entirely as if he had obtained the ownership of the land, but his precarious and revocable tenure of which, at the same time, kept him bound to his lord in the same dependence as before.

Here then we have the union of the feud and vassalage—two things which remained intimately and inseparably combined so long as the feudal system existed. They may have originally been quite distinct, and merely been thrown into combination by circumstances. It is possible that there were vassals who were not feudatories, or feudatories who were not vassals. But when the advantage of the association of the two characters came to be perceived, it would be established as essential to the completeness of each. Every vassal would have a fief, and every person to whom a fief was granted would be a vassal, and thus a vassal and the holder of a fief come to signify one and the same thing.

Fiefs are supposed to have been at first entirely precarious, that is to say, resumable at any time at the pleasure of the grantor. But if this state of things ever existed, it probably did not last long. Even from the first it is most probable that many fiefs were granted for a certain term of years or for life. And in those of all kinds a substitute for the original precariousness of the tenure was soon found, which while it equally secured the rights and interests of the lord, was much more honourable and in every way more advantageous for the vassal. This was the method of attaching him by certain oaths and solemn forms, which, besides their force in a religious point of view, were so contrived as to appeal also to men's moral feelings, and which therefore it was accounted not only impious but infamous to violate. The relation binding the vassal to his lord was made to wear all the appearance of a mutual interchange of benefits,—of bounty and protection on the one hand, of gratitude and service due on the other; and so strongly did this view of the matter take possession of men's minds, that in the feudal ages even the ties of natural relationship were looked upon as of inferior obligation to the artificial bond of vassalage.

As soon as the position of the vassal had thus been made stable and secure, various changes would gradually introduce themselves. The vassal would begin to have his fixed rights as well as his lord, the oath which he had taken measuring and determining both these rights and his duties. The relation between the two parties would cease to be one wholly of power and dominion on the one hand, and of mere obligation and dependence on the other. If the vassal performed that which he had sworn, nothing more would be required of him. Any attempt of his lord to force him to do more would be considered an injustice. Their connection would now assume the appearance of a mutual compact, imposing corresponding obligations upon both, and making protection as much a duty in the lord as gratitude and service in the vassal.

Other important changes would follow this fundamental change, or would take place while it was advancing to completion. After the fief had come to be generally held for life, the next step would be for the eldest son usually to succeed his father. His right so to succeed would next be established by usage. At a later stage fiefs would become, as they did, descendible in the collateral as well as in the direct line. At a still later, they became inheritable by females as well as by males. There is much difference of opinion, however, as to the dates at which these several changes took place. Some writers conceive that fiefs first became hereditary in France under Charlemagne; others, however, with whom Mr. Hallam agrees, maintain that there were hereditary fiefs under the first race of French kings. It is supposed not to have been till the time of the first Capets in the end of the 10th century that the right of the son to succeed the father was established by law in France. Conrad II., surnamed the Salic, who became emperor in 1024, is generally believed to have first established the hereditary character of fiefs in Germany.

Throughout the whole of this progressive development of the system, however, the original nature of the fief was never forgotten. The ultimate property was still held to be in the lord; and that fact was very distinctly signified, not only by the expressive language of forms and symbols, but by certain liabilities of the tenure that gave still sharper intimation of its true character. Even after fiefs became descendible to heirs in the most comprehensive sense, and by the most fixed rule, every new occupant of the estate had still to make solemn acknowledgement of his vassalage, and thus to obtain, as it were, a renewal of the grant from the lord. He became bound to discharge all services and other dues as fully as the first grantee had been. Above all, in certain circumstances, as, for example, if the tenant committed treason or felony, or if he left no heir, the estate would still return by forfeiture or escheat to the lord, as to its original owner.

Originally fiefs were granted only by sovereign princes; but after estates of this description, by acquiring the hereditary quality, came to be considered as property to all practical intents and purposes, their holders proceeded, on the strength of this completeness of possession, themselves to assume the character and to exercise the rights of lords, by the practice of what was called subinfeudation, that is, the alienation of portions of their fiefs to other parties, who thereupon were placed in the same or a similar relation to them as that in which they stood to the prince. The vassal of the prince became the lord over other vassals; in this latter capacity he was called a mesne (that is, an intermediate) lord; he was a lord and a vassal at the same time. In the same manner the vassal of a mesne lord might become also the lord of other arrere vassals, as those vassals that held of a mesne lord were designated. This process sometimes produced curious results; for a lord might in this way actually become the vassal of his own vassal, and a vassal lord over his own lord.

From whatever cause it may have happened (which is matter of dispute), in all the continental provinces of the Roman empire which were conquered and occupied by the Germanic nations, many lands were from the first held, not as fiefs, that is, with the ownership in one party and the usufruct in another, but as allodia, that is, in full and entire ownership. [ALLODIUM.] The holder of such an estate, having no lord, was of course free from all the exactions and burdens which were incidental to the vassalage of the holder of a fief. He was also, however, without the powerful protection which the latter enjoyed; and so important was this protection in the turbulent state of society which existed in Europe for some ages after the dissolution of the empire of Charlemagne, that in fact most of the allodialists in course of time exchanged their originally independent condition for the security and subjection of that of the feudatory. "During the 10th and 11th centuries," says Mr. Hallam, "it appears that allodial lands in France had chiefly become feudal; that is, they had been surrendered by their proprietors, and received back again upon the feudal conditions; or, more frequently perhaps, the owner had been compelled to acknowledge himself the man or vassal of a suzerain, and thus to confess an original grant which had never existed. Changes of the same nature, though not perhaps so extensive or so distinctly to be traced, took place in Italy and Germany. Yet it would be inaccurate to assert that the prevalence of the feudal system has been unlimited; in a great part of France allodial tenures always subsisted, and many estates in the empire were of the same description."

After the conquest of England by the Normans, the *dominium directum*, or property of all the land in the kingdom, was considered as vested in the crown. "All the lands and tenements in England in the hands of subjects," says Coke, "are holden mediately or immediately of the king; for in the law of England we have not properly allodium." This universality of its application therefore may be regarded as the first respect in which the system of feudalism established in England differed from that established in France and other continental countries. There were also various other differences. The Conqueror, for instance, introduced here the practice unknown on the continent of compelling the arrere vassals, as well as the immediate tenants of the crown, to take the oath of fealty to himself. In other countries a vassal only swore fealty to his immediate lord; in England, if he held of a mesne lord, he took two oaths, one to his lord and another to his lord's lord. It may be observed, however, that in those times in which the feudal principle was in its greatest vigour the fealty of a vassal to his immediate lord was usually considered as the higher obligation; when that and his fealty to the crown came into collision, the former was the oath to which he adhered. Some feudists indeed held that his allegiance to the crown was always to be understood as reserved in the fealty which a vassal swore to his lord; and the Emperor Frederick Barbarossa decreed that in every oath of fealty taken to an inferior lord there should be an express reservation of the vassal's duty to the emperor. But the double oath exacted by the Norman conqueror did not go so far as this. It only gave him at the most a concurrent power with the mesne lord over the vassals of the latter, who in France were nearly removed altogether from the control of the royal authority. A more important difference between the English and French feudalism consisted in the greater extension given by the former to the rights of lords generally over their vassals by what were called the incidents of wardship and marriage. The wardship or guardianship of the tenant during minority, which implied both the custody of his person and the appropriation of the profits of the estate, appears to have been enjoyed by the lord in some parts of Germany, but no where else except in England and Normandy. The right of marriage (maritagium) originally implied only the power possessed by the lord of tendering a husband to his female ward while under age: if she rejected the match, she forfeited the value of the marriage; that is, as much as any one would give to the lord for permission to marry her. But the right was afterwards extended so as to include male as well as female heirs; and it also appears that although the practice might not be sanctioned by the law, some of the Anglo-Norman kings were accustomed to exact penalties from their female vassals of all ages, and even from widows, for either marrying without their consent, or refusing such marriages as they proposed. The seignorial prerogative of marriage, like that of wardship, was peculiar to England and Normandy, and to some parts of Germany.

It has been very usual to represent military service as the essential peculiarity of a feudal tenure. But the constituent and distinguishing element of that form of tenure was its being a tenancy merely, and not an ownership; the enjoyment of land for certain services to be performed. In the state of society however in which the feudal system grew up, it was impossible that military service should not become the chief duty to which the vassal was bound. It was in such a state of society the most important service which he could render to his lord. It was the species of service which the persons to whom fiefs were first granted seem to have been previously accustomed to render, and the continuance of which accordingly the grant of the fief was chiefly intended to secure. Yet military service, or knight service, as it was called in this country, though the usual, was by no means the necessary or uniform condition on which fiefs were granted. Any other honourable condition might be imposed which distinctly recognised the *dominium directum* of the lord. [KNIGHT-SERVICE.]

Another common characteristic of fiefs, which in like manner arose incidentally out of the circumstances of the times in which they originated, was that they usually consisted of land. Land was in those times nearly the only species of wealth that existed; certainly the only form of wealth that had any considerable security or permanency. Yet there are not wanting instances of other things, such as pensions and offices, being granted as fiefs. It was a great question nevertheless among the feudists whether a fief could consist of money, or of any thing else than land; and the most eminent authorities have maintained that it could not. The preference thus shown for land by the spirit of the feudal customs has perhaps left deeper traces both upon the law, the political constitution, and the social habits and feelings of our own and other feudal countries than any other part of the system. We have thence derived not only the marked distinction by which our law still discriminates certain amounts of interest in lands and tenements under the name of *real* property from property of every other kind, but also the ascendency retained by the former in nearly every respect in which such ascendency can be upheld either by institutions or by opinion.

The grant of land as a fief, especially when it was a grant from the suzerain, or supreme lord, whether called king or duke, or any other name, was, sometimes at least, accompanied with an express grant of jurisdiction. Thus every great tenant exercised a jurisdiction civil and criminal over his immediate tenants: he held courts and administered the laws within his lordship like a sovereign prince. It appears that the same jurisdiction was often granted by the crown to the abbeys with their lands. The formation of MANORS in this country appears to have been consequent upon the establishment of feudalism. The existence of manor-courts, and so many small jurisdictions within the kingdom, is one of the most permanent features of that polity which the Normans stamped upon this country.

In the infancy of the feudal system it is probable that the vassal was considered bound to attend his lord in war for any length of time during which his services might be required. Afterwards, when the situation of the vassal became more independent, the amount of this kind of service was fixed either by law or by usage. In England the whole country was divided into about 60,000 knights' fees; and the tenant of each of these appears to have been obliged to keep the field at his own expense for forty days on every occasion on which his lord chose to call upon him. For smaller quantities of land proportionately shorter terms of service were due: at least such is the common statement; although it seems improbable that the individuals composing a feudal army could thus have the privilege of returning home some at one time, some at another. Women were obliged to send their substitutes; and so were the clergy, certain persons holding public offices, and men past the age of sixty, all of whom were exempted from personal service. The rule or custom however both as to the duration of the service, and its extent in other respects, varied greatly in different ages and countries.

The other duties of the vassal were rather expressive of the relation of honourable subordination in which he stood to his lord than services of any real or calculable value. They are thus summed up by Mr. Hallam:—"It was a breach of faith to divulge the lord's counsel, to conceal from him the machinations of others, to injure his person or fortune, or to violate the sanctity of his roof and the honour of his family. In battle he was bound to lend his horse to his lord when dismounted; to adhere to his side while fighting, and to go into captivity as a hostage for him when taken. His attendance was due to the lord's courts, sometimes to witness and sometimes to bear a part in the administration of justice."

There were however various other substantial advantages derived by the lord. We have already mentioned the rights of wardship and of marriage, which were nearly peculiar to the dominions of the English crown. Besides these, there were the payment, called a relief, made by every new entrant upon the possession of the fief, the escheat of the land to the lord when the tenant left no heir, and its forfeiture to him when the tenant was found guilty either of a breach of his oath of fealty, or of felony. There was besides a fine payable to the lord upon the alienation by the tenant of any part of the estate, if that was at all permitted. Finally, there were the various aids, as they were called, payable by the tenant. "These," observes Mr. Hallam, "depended a great deal upon local custom, and were often extorted unreasonably. Du Cange mentions several as having existed in France; such as an aid for the lord's expedition to the Holy Land, for marrying his sister or eldest son, and for paying a relief to his suzerain on taking possession of his land. Of these the last appears to have been the most usual in England. But this and other aids occasionally exacted by the lords were felt as a severe grievance; and by Magna Charta three only are retained—to make the lord's eldest son a knight, to marry his eldest daughter, and to redeem his person from prison. They were restricted to nearly the same description by a law of William I. of Sicily, and by the customs of France. These feudal aids are deserving of our attention as the beginnings of taxation, of which for a long time they in a great measure answered the purpose, till the craving necessities and covetous policy of kings substituted for them more durable and onerous burthens."

The principal ceremonies used in conferring a fief were homage, fealty, and investiture. The two first of these cannot be more distinctly or more shortly described than in the words of Littleton: "Homage is the most honourable service, and most humble service of reverence, that a frank tenant may do to his lord: for when the tenant shall make homage to his lord, he shall be ungirt and his head uncovered, and his lord shall sit and the tenant shall kneel before him on both his knees, and hold his hand jointly together between the hands of his lord, and shall say thus: I become your man, from this day forward, of life and limb, and of earthly worship, and unto you shall be true and faithful, and bear you faith for the tenements that I claim to hold of you, saving the faith that I owe to our sovereign lord the king; and then the lord, so sitting, shall kiss him." Religious persons and women instead of "I become your man," said, "I do homage unto you." Here it is to be observed there was no oath taken; the doing of fealty consisted wholly in taking an oath, without any obeisance. "When a freeholder (frank tenant)," says Littleton, "doth fealty to his lord, he shall hold his right hand upon a book, and shall say thus: Know ye this, my lord, that I shall be faithful and true unto you, and faith to you shall bear for the lands which I claim to hold of you, and that I shall lawfully do to you the customs and services which I ought to do at the terms assigned, so help me God and his saints; and he shall kiss the book. But he shall not kneel when he maketh his fealty, nor shall make such (that is, any such, *tiel*,) humble reverence as is aforesaid in homage." "Investiture or the actual conveyance of feudal lands," says Mr. Hallam, "was of two kinds; proper and improper. The first was an actual putting in possession upon the ground, either by the lord or his deputy; which is now called in our law livery of seisin. The second was symbolical, and consisted in the delivery of a turf, a stone, a wand, a branch, or whatever else might have been made usual by the caprice of local custom. Du Cange enumerates not less than 98 varieties of investitures." The mode of conveying lands in England by feoffment is derived from the feudal investiture. [Feoffment.] The practice of giving infeftment in Scotland, is neither more nor less than symbolical investiture.

The feudal system may be regarded as having nearly reached its maturity and full development at the time of the Norman conquest. It appears accordingly to have been established here immediately or very soon after that event in as pure, strict, and comprehensive a form as it ever attained in any other country. The whole land of the kingdom, as we have already mentioned, was without any exception either in the hands of the crown, or held in fief by the vassals of the crown, or of them by sub-infeudation. Those lands which the king kept were called his demesne (the Terræ Regis of the Domesday Survey), and thus the crown had a number of immediate tenants, like any other lord, in the various lands reserved in nearly every part of the kingdom. No where else, also, before the restrictions established by the charters, were the rights of the lord over the vassal stretched in practice nearer to their extreme theoretical limits. On the other hand, the vassal had arrived at what we may call his ultimate position in the natural progress of the system; the hereditary quality of feuds was fully established; his ancient absolute dependence and subjection had passed away; under whatever disadvantages his inferiority of station might place him, he met his lord on the common ground of their mutual rights and obligations; there might be considerable contention about what these rights and obligations on either side were, but it was admitted that on both sides they had the same character of real, legally binding obligations, and legally maintainable rights.

This settlement of the system however was anything rather than an assurance of its stability and permanency. It was now held together by a principle altogether of a different kind from that which had originally created and cemented it. That which had been in the beginning the very life of the relation between the lord and the vassal had now in great part perished. The feeling of gratitude could no more survive than the feeling of dependence on the part of the latter after feuds became hereditary. A species of superstition, indeed, and a sense of honour, which in some degree supplied the place of what was lost, were preserved by oaths and ceremonies, and the influence of habit and old opinion; but these were at the best only extraneous props; the self-sustaining strength of the edifice was gone. Thus it was the tendency of feudalism to decay and fall to pieces under the necessary development of its own principle.

Other causes called into action by the progress of events conspired to bring about the same result. The very military spirit which was fostered by the feudal institutions, and the wars, defensive and aggressive, which they were intended to supply the means of carrying on, led in course of time to the release of the vassal from the chief and most distinguishing of his original obligations, and thereby, it may be said, to the rupture of the strongest bond that had attached him to his lord. The feudal military army was at length found so inconvenient a force that soon after the accession of Henry II. the personal service of vassals was dispensed with, and a pecuniary payment, under the name of escuage, accepted in its stead. From this time the vassal was no longer really the defender of his lord; he was no longer what he professed to be in his homage and his oath of fealty; and one effect of the change must have been still farther to wear down what remained of the old impressiveness of these solemnities, and to reduce them nearer to mere dead forms. The acquisition by the crown of an army of subservient mercenaries, in exchange for its former inefficient and withal turbulent and unmanageable army of vassals, was in fact the discovery of a substitute for the main purpose of the feudal polity. Whatever nourished a new power in the commonwealth, also, took sustenance and strength from this ancient power. Such must in an especial degree have been the effect of the growth of towns, and of the new species of wealth, and, it may be added, the new manners and modes of thinking, created by trade and commerce.

The progress of sub-infeudation has sometimes been represented as having upon the whole tended to weaken and loosen the fabric of feudalism. It "demolished," observes Blackstone (ii. 4), "the ancient simplicity of feuds; and an inroad being once made upon their constitution, it subjected them in a course of time to great varieties and innovations. Feuds began to be bought and sold, and deviations were made from the old fundamental rules of tenure and succession, which were held no longer sacred when the feuds themselves no longer continued to be purely military." But the practice of sub-infeudation would rather seem to have been calculated to carry out the feudal principle, and to place the whole system on a broader and firmer basis, and this has been found to be the effect in Scotland. It would be more correct to ascribe the demolition of the fabric of feudalism, to which we have now nearly arrived, to the prohibition against sub-infeudation. The effect of this practice was to deprive the lord of his forfeitures and escheats and the other advantages of his seigniory, and various attempts therefore were made to check or altogether prevent it, in which the crown and the tenants in chief, whose interests were most affected, seem to have joined. One of the clauses of the great charter of Henry III. (the thirty-second) appears to be intended to restrict sub-infeudation (although the meaning is not quite clear), and it is expressly forbidden by the statute of *Quia Emptores* (18 Edw. I., c. 1). This however was originally the only way in which the holder of a fief could alienate any part of his estate without the consent of his lord; and it therefore became necessary to provide some other mode of effecting that object, for it seems to have been felt that after alienation had been allowed so long to go on under the guise of sub-infeudation, to restrain it altogether would be no longer possible. The consequence was, that, as a compensation for the prohibition of sub-infeudation, the old prohibition against alienation was removed; lands were allowed to be alienated, but the purchaser or grantee did not hold them of the vendor or grantor, but held them exactly as the grantor did; and such is still the legal effect in England when a man parts with his entire interest in his lands. This change was effected by the statute of *Quia Emptores* with regard to all persons except the immediate tenants of the crown, who were permitted to alienate on paying a fine to the king by the statute 1 Edw. III. c. 12. Thus at the same time that a practice strictly accordant to the spirit of feudalism, and eminently favourable to its conservation and extension, was stopped, another practice, altogether adverse to its fundamental principles, was introduced and established, that of allowing *voluntary* alienation by persons during their lifetime.

It was a consequence of feudal principles, that a man's lands could not be subjected to the claims of his creditors. This restraint upon what may be called *involuntary* alienation has been removed by the successive enactments which have had for their object to make a man's lands liable for his debts: although, it is only after a lapse of nearly six hundred years since the statute of Acton Burnell, that the lands of a debtor have been subjected to the just demands of his creditors. This statute of Acton Burnell, passed 11 Ed. I. (1283), made the devisable burgages, or burgh tenements, of a debtor saleable in discharge of his debts. By the Statute of Merchants (13 Ed. I., st. 13), a debtor's lands might be delivered to his merchant creditor till his debt was wholly paid out of the profits. By the 18th chapter of the Statute of Westminster the Second, passed the same year, a moiety of a debtor's land was subjected to execution for debts recovered by judgment [Elegit]; and finally, by several modern statutes, the whole of a bankrupt debtor's lands have become absolutely saleable for the payment of his debts. Further, by 3 & 4 Will. IV. c. 104, all a deceased person's estate in lands, of whatever kind, is liable to the payment of his debts, both those on specialty and those on simple contract.

An attempt had early been made to restore in part the old restraints upon *voluntary* alienation by the statute 13 Ed. I. c. 1, entitled 'De Donis Conditionalibus,' which had for its object to enable any owner of an estate, by his own disposition, to secure its descent in perpetuity in a particular line. So far as the statute went, it was an effort to strengthen the declining power of feudalism. The effect was to create what were called estates tail, and to free the tenant in tail from many liabilities of his ancestor to which he would be subject if he were seised of the same lands in fee-simple. [Estate.] The power which was thus conferred upon landholders of preventing the alienation of their lands remained in full force for nearly two centuries, till at last, in the reign of Edward IV., by the decision of the courts (A.D. 1472) the practice of barring estates tail by a common recovery was completely established. [Recovery, Common.]

The practice of conveying estates by fine, which was of great antiquity in England, and the origin of which is referred to the time of Stephen or Henry II., was regulated by various statutes (among others, by 4 Henry VII.) and contributed materially to facilitate the transfer of lands in general, but more particularly to bar estates tail.

[Fine.] By 32 Henry VIII. c. 28, tenants in tail were enabled to make leases for three lives or twenty-one years, which should bind their issue. The 26 Henry VIII. c. 13, also, had declared all estates of inheritance, in use or possession, to be forfeited to the king upon any conviction of high treason, and thus destroyed one of the strongest inducements to the tying up of estates in tail, which hitherto had only been forfeitable for treason during the life of the tenant in tail.

Another mode by which the feudal restraints upon *voluntary* alienation came at length to be extensively evaded was the practice introduced, probably about the end of the reign of Edward III., of granting lands to persons to *uses*, as it was termed; that is, the new owner of the land received it not for his own use, but on the understanding and confidence that he would hold the land for such persons and for such purposes as the grantor then named or might at any time afterwards name. Thus an estate in land came to have two qualities or natures, so to speak, one of which was the legal ownership, and the other the right to the profits or the *use;* and this use could be transferred by a man's last *will* at a time when, the land itself being still bound in the fetters of feudal restraint, could not be transferred by will, except where it was devisable, as in Kent and some other parts of England, by special custom. The person who thus obtained the use or profits of the estate—the *cestui que use*, as he is called in law—was finally converted into the actual owner of the land to the same amount of interest as he had in the use (A.D. 1535) by the Statute of Uses (27 Hen. VIII. c. 10), and thus the power of devising land which had been enjoyed by the mode of uses was taken away. But this important element in the feudal system, the restraint on the disposition of lands by will, could no longer be maintained consistently with the habits and opinions then established, and accordingly, by stat. 32 Hen. VIII. (explained by 34 Hen. VIII.), all persons were allowed to dispose of their freehold lands held in fee-simple by a will in writing, subject to certain restrictions as to lands held by knight service either of the king or any other, which restrictions were removed by the stat. 12 Chas. II. c. 24, which abolished military tenures. [Uses.]

Notwithstanding these successive assaults upon certain parts of the ancient feudalism, the main body of the edifice still remained almost entire. It is said that the subject of the abolition of military tenures was brought before the parliament in the 18th of James I., on the king's recommendation; but at that time nothing was done in the matter. When the civil war broke out in 1641, the profits of marriage, wardship, and of most of the other old feudal prerogatives of the crown, were for some time still collected by the parliament, as they had formerly been by the king. The fabric of the feudal system in England, however, was eventually shattered by the storm of the great rebellion. The Court of Wards was in effect discontinued from 1645. The restoration of the king could not restore what had thus been in practice swept away. By the above-mentioned statute (12 Car. II. c. 24) it was accordingly enacted, that from the year 1645 the Court of Wards and Liveries, and all wardships, liveries, primer-seisins, values, and forfeitures of marriage, &c., by reason of any tenure of the king's majesty, or of any other by knights' tenures, were taken away and discharged, together with all fines for alienations, tenure by homage, escuage, aids pur file marrier and pur fair fitz chevalier, &c.; and that all tenures of any honours, manors, lands, tenements or hereditaments, or any estate of inheritance at the common law, held either of the king or of any other person or persons, bodies politic or corporate, were turned into free and common soccage, to all intents and purposes. [Soccage.] By the same statute, every father was empowered by deed or will, executed in the presence of two witnesses, to appoint persons to have the guardianship of his infant and unmarried children, and to have the custody and management of their property. It was not till after the lapse of nearly another century that similar incidents of feudalism were put an end to in Scotland by two statutes, passed after the Rebellion,—the 20 Geo. II. c. 43, entitled 'An Act for abolishing Heritable Jurisdictions;' and the 20 Geo. II. c. 50, entitled 'An Act for taking away the Tenure of Wardholding in Scotland.' It is only within the last few years that estates-tail in Scotland have been relieved from the strictest fetters of a destination in perpetuity.

We have enumerated the principal statutes which may be considered as having broken in upon the integrity of the feudal system, considered in reference to the power which the *tenant* of land can now exercise over it, and the right which others can enforce against him in respect of his property in it. But the system of tenures still exists. The statute of Charles II. only abolished military tenures and such parts of the feudal system as had become generally intolerable; but all lands in the kingdom are still held either by soccage tenure, into which military tenures were changed, or else by the respective tenures of frankalmoyne, grand serjeanty, and copyhold, which were not affected by the statute.

Some of the consequences of tenures, as they at present subsist, cannot be more simply exemplified than by the rules as to the Forfeiture and Escheat of lands, both of which, however, have undergone modifications since the statute of Charles II.

To attain a comprehensive and exact view of the present tenures of landed property in England and their incidents and consequences, it would be necessary for the reader to enter upon a course of study more laborious and extensive than is consistent with pursuits not strictly legal. Still a general notion may be acquired of their leading characteristics by referring to several of the articles already quoted, and to such heads as Attainder, Baron, Copyhold, Courts, Distress, Estate, Lease, Manor, Tenures, and such other articles as may be referred to in those last mentioned.

The notions of loyalty, of honour, of nobility, and of the importance, socially and politically, of landed over other property, are the most striking of the feelings which may be considered to have taken their birth from the feudal system. These notions are opposed to the tendency of the commercial and manufacturing spirit which has been the great moving power of the world since the decline of strict feudalism; but that power has not yet been able to destroy, or perhaps even very materially to weaken, the opinions above mentioned in the minds of the mass.

We are not, however, to pass judgment upon feudalism, as the originating and shaping principle of a particular form into which human society has run, simply according to our estimate of the value of these its relics at the present day. The true question is, if this particular organisation had not been given to European society after the dissolution of the ancient civilisation, what other order of things would in all likelihood have arisen, a better or a worse than that which did result? Some assistance in settling this question might perhaps be obtained by comparing the history of society, from this date, in the feudal countries, with its history in those parts of Europe to which feudalism never reached,—France or England, for instance, with Denmark, Sweden, or Hungary.

As for the state of society during the actual prevalence of the feudal system, it was without doubt in many respects exceedingly defective and barbarous. But the system, with all its imperfections, still combined the two essential qualities of being both a system of stability and a system of progression. It did not fall to pieces, neither did it stand still. Notwithstanding all its rudeness, it was, what every right system of polity is, at once conservative and productive. And perhaps it is to be most fairly appreciated by being considered, not in what it actually was, but in what it preserved from destruction, and in what it has produced.

The earliest published compilation of feudal law was a collection of rules and opinions supposed to have been made by two lawyers of Lombardy, Obertus of Otto and Gerardus Niger, by order of the Emperor Frederic Barbarossa. It appeared at Milan about the year 1170, and immediately became the great text-book of this branch of the law in all the schools and universities, and even a sort of authority in the courts. It is divided in some editions into three, in others into five books, and is commonly entitled the 'Libri Feudorum;' the old writers, however, are wont to quote it simply as the Textus, or Text. But the great sources of the feudal law are the ancient codes of the several Germanic nations; the capitularies or collections of edicts of Charlemagne and his successors; and the various Coutumiers or collections of the old customs of the different provinces of France. The laws of the Visigoths, of the Burgundians, the Salic law, the laws of the Alemanni, of the Baiuvarii, of the Ripuarii, of the Saxons, of the Anglii, of the Werini, of the Frisians, of the Lombards, &c., have been published by Lindenbrogius in his 'Codex Legum Antiquarum,' fol., Francof., 1613. The best editions of the capitularies are that by Baluze, in 2 vols. fol., Paris, 1677, and that by Chiniac, of which, however, we believe only the first two volumes have appeared, Paris, fol., 1780. Richebourg's 'Nouveau Coutumier Général,' 4 vols. fol., Paris, 1724, is a complete collection of the Coutumiers, all of which, however, have also been published separately. All these old laws and codes, as well as the Milan text-book, have been made the subject of voluminous commentaries.

FEVER, CONTINUED. Under the name fever are included various diseases which are distinguished by some term prefixed to this word, as scarlet fever, inflammatory fever, yellow fever, continued fever, intermittent fever, remittent fever, and such like. There can be little doubt that this term fever has been applied to very opposite and different states of the system, and the only idea implied by the word is a certain continuity in the disease, and perhaps a tendency in the diseased processes to come to a natural termination. The term fever is however frequently applied alone to that group of diseases to which recent medical writers have applied the term "continued fevers." This expression continued distinguishes them more especially from the fevers called intermittent [Ague], remittent [Hydrocephalus], and yellow fevers. By some writers it is supposed that the various forms of continued fever are but modifications of that same state of the system in which intermittent, remittent, and yellow fevers come on. There is however good reason to believe that ague and remittent and yellow fevers arise from causes different from those producing continued fevers. Hence they are now regarded as distinct. Dr. Jenner, who has recently written on this subject, sums up the forms of continued fever in the following manner.

"*Febricula*—A disease attended by chilliness, alternating with a sense of heat, headache, white tongue, confined bowels, high-coloured scanty urine, hot and dry skin, and frequent pulse, terminating in from two to seven days, and having for its cause excess, exposure, over-fatigue, &c.—(*i.e.*) the cause of febricula is not specific.

"*Relapsing Fever.*—A disease arising from a specific cause, attended by rigors and chilliness, headache, vomiting, white tongue, epigastric tenderness, confined bowels, enlarged liver and spleen, high-coloured urine, frequent pulse, hot skin, and occasionally by jaundice, and terminating in apparent convalescence in from five to eight days; in a week a relapse—(*i.e.*) a repetition of the symptoms present during the primary attack. After death, spleen and liver are found considerably enlarged; absence of marked congestion of internal organs.

"*Typhoid Fever.*—A disease arising from a specific cause, attended by rigors, chilliness, headache, successive crops of rose spots, frequent pulse, sonorous râle, diarrhœa, fulness, resonance, and tenderness of the abdomen, gurgling in the right iliac fossa, increased splenic dulness, delirium, dry and brown tongue, and prostration, and terminating by the 30th day. After death enlargement of the mesenteric glands, disease of Peyer's patches, enlargement of the spleen, disseminated ulcerations, disseminated inflammations.

"*Typhus Fever.*—A disease arising from a specific cause, attended by rigors, chilliness, headache, mulberry rash, frequent pulse, delirium, dry brown tongue, and prostration, and terminating by the twenty-first day. After death, disseminated and extreme congestions; in young persons, enlargement of the spleen." ('Medical Times,' 20th Paper.)

We may take, for the convenience of describing the condition of the system in the state of continued fever, the ordinary continued fever of this country, the disease denominated Common Continued Fever (Synochus Mitior). The phenomena which take place in this disease, and the order in which they succeed each other, are the following:—

The first event in the series is the derangement of the functions of the nervous system. There is reason to believe that this derangement takes place primarily in the organic system of nerves, that system which presides over the nutrition of the organs, and consequently that the very first effect of the noxious agent, whatever it be, which produces fever, is to disorder the health of the organs, and thereby to impair their energy.

Though it is probable that a disorder of the organic nerves is the first event that actually takes place in fevers, yet the first event of which we become conscious would seem to be a derangement in the second portion of the nervous system, the great nervous centres in which sensation, intellectual operation, and voluntary motion have their seat, namely, the brain and spinal cord. The organic functions being carried on without consciousness, we can know that they are disordered only by their producing disturbance in some part of the sentient system. The organic portion of the nervous system is most intimately connected with the sentient portion, and any disorder of the former is quickly extended to the latter. In an attack of fever the disordered condition of the brain is indicated by a loss of mental energy. But this loss of mental energy, though it is probably the very first indication of fever of which any one can be conscious, is by no means the first symptom which usually attracts attention. In general the loss of mental power is not observed until it becomes distressing, which does not often happen until the progress of the disease is further advanced. The loss of mental power is indicated by the inability to perceive clearly the trains of ideas, and to attend closely to their relation; whence result indistinctness and confusion of mind, and the want of capacity to form a sound judgment.

As this state of the mind depends on the disordered condition of the organ in which the mind has its seat, the brain, and as the servant of the mind, volition, has its seat in the same portion of the nervous system: closely connected with this mental weakness, is the loss of energy in the muscles of voluntary motion. Lassitude is the result. The movements of the body are feeble and unsteady, as the energy of the mind is impaired.

From this morbid condition of the brain and of the muscles of voluntary motion, there results an uneasy sensation, of which no idea can be conveyed by words; it must be felt to be understood. It is not pain, it is more distressing than pain; even the mere restlessness which accompanies, and which forms so large a part of it, any one would gladly exchange for intense pain: it is this state which has been appropriately and expressly named 'Febrile Uneasiness.'

But very soon there is superadded to this uneasy sensation positive pain. In general pain is first felt in the back and loins, and in the limbs. It is rare that this symptom is absent in the commencement of this form of fever, and it often occasions more distress to the patient than anything else during the first stage of the disease.

The remaining part of the history of an attack of common continued fever has been thus given by a physician who has had the most abundant opportunities of witnessing the progress of the disease:—

Already a remarkable change is commonly visible in the countenance. Its expression is that of dejection; it is often strikingly similar to that of a very weak person suffering from fatigue. The colour of face is pallid, and the features are somewhat shrunk; but its general aspect is so peculiar and characteristic, that an experienced eye can distinguish the disease, even at this early period, and without asking a single question. The skin partakes in a remarkable degree of the debility which so early shows itself in the muscles of locomotion. This is indicated in a striking manner by its increasing sensitiveness to the physical agents by which it is surrounded, and by its inability to resist their influence. Ordinary degrees of temperature produce a sensation of cold which is sometimes intolerable; chilliness is felt even in a heated room, or in a warm bed; hence the sensation of cold, sometimes increasing to shivering, which has been considered one of the most constant signs of fever. But this feeling of chilliness by no means depends on external temperature: it is increased by cold, but it exists in spite of an elevated temperature; it arises from an internal cause, and is not to be counteracted by external heat.

While the patient experiences the sensation of cold, there is no diminution of the quantity of caloric in the system. The thermometer applied to any part of the body commonly rises as high as in the state of health; and the skin, touched by the hand of another person, communicates not the feeling of cold, but often, on the contrary, that of preternatural heat. There is no positive abstraction of caloric from the body, nor any failure in the process, whatever it be, by which animal heat is generated: there is only altered sensation, in consequence of derangement in the function of the skin. In this form of fever the chilliness in many cases never amounts to shivering; in others there is an attack of well-marked rigor, and in others, again, there is either no feeling of cold, or it is so slight that it escapes observation.

The symptoms now enumerated are all clearly referrible to derangement of the functions of the spinal cord and brain. There is as yet no affection of any other organ obviously or at least much developed. The circulating system, it is true, is just beginning to be affected. The pulse is no longer perfectly natural; it is more languid than in the state of health; sometimes it is also quicker; at other times it is slower; now and then it is scarcely changed in frequency, but its action is invariably weaker than in its sound state.

At the same time the respiration is affected in a corresponding degree; it is shorter and quicker than natural: the chest does not expand so freely, and compensation seems to be sought in an additional number of respirations. Oftentimes neither the pulse nor the respiration appears to be much altered, if the patient remain perfectly still; but if he rise and walk across the room the pulse instantly becomes rapid, and the respiration is quickened almost to fainting.

The transition from the affection of the nervous and sensorial to that of the circulating and respiratory systems is thus clear and striking. Physiology teaches us how closely these systems are connected, and how mutually they are dependant one upon the other, the closest observers and the ablest experimentalists candidly confessing that they are scarcely able to determine which is the least dependant, or the action of which is the least necessary to the other's performance of its functions. The nervous system being first deranged, it is thus consonant to what we know of the healthy function of the animal economy that the circulating and the respiratory systems should be the next to suffer.

How long the nervous system may continue thus deranged before any other organs are involved, excepting the circulating and the respiratory, to the extent just stated, is uncertain. There can be no doubt that in this mild form of fever the range of the duration of this isolated state of disorder, if we may so express it, is from a few hours to several days. The rapidity or the slowness with which other systems of organs become involved seems to depend very much upon the acuteness of the attack. In general, the more acute the fever, the more rapidly the individual phenomena succeed each other, and the entire series becomes complete. But this is not, and it is important to bear in mind that it is not, invariably the case, for experience teaches us that the severity and danger of the disease are not diminished by the slowness of its approach; and that cases occur which are slow in forming, and which do not for a while excite alarm, that ultimately become truly formidable.

It has been stated that the circulation languishes with the diminished energy in the sensorial faculties, and the loss of power in the muscles of locomotion. After a while the pulse, which was feebler than natural, becomes more full, more strong, and generally more quick than in a sound state; and now the skin, which was cold, becomes preternaturally hot. The previous cold consisted, for the most part, of altered sensation, there being little or no loss of caloric; but the feeling of heat, on the contrary, is the result of an actual increase of temperature: for the heat in the interior of the body, as well as on the surface, rises in some cases several degrees, as is ascertained by the thermometer, the range of increase being from the natural standard 98° to 105°, beyond which it is seldom found to augment in this form of fever. The heat is at first not uniform over the entire surface of the body: it often happens that some parts are cold while others are burning hot. The heat is oftentimes particularly intense over the forehead or over the back part of the head, or over the whole scalp, while the cheeks are commonly flushed. All these symptoms denote a morbid condition in the action of the heart and arteries. Since the generation of animal heat is so intimately connected with the circulating and the respiratory functions, it is probable that the increase of temperature is the result of some morbid action of the capillary vessels belonging to these systems. What the disordered action of these vessels is which produces increase of temperature we do not know; but the object of scientific observation is in some degree accomplished when it is ascertained that one condition of these functions is invariably connected with a morbidly diminished temperature; another with a morbidly augmented temperature; and another with the temperature of health.

Immediately the circulation is thus excited, the functions of secretion and excretion become deranged. The mouth is now dry and parched; the tongue begins to be covered with fur; thirst comes on; the secretion of the liver, probably also of the pancreas, and certainly of the mucous membrane lining the whole alimentary canal, is vitiated, as is proved by the unnatural quantity, colour, and fetor of the evacuations; the urine likewise is altered in appearance, and the skin is not more remarkable for the sense of heat than for that of dryness and harshness which it communicates to the touch. With the excitement of the pulse and the increase of the heat, the pain in the back and limbs, and the general febrile uneasiness are much augmented.

At this period, then, the fever is fully formed; the series of morbid phenomena is complete: anything more that happens is referrible to degree and to duration, and must be the result of one or other of these circumstances, or of their combined operation.

As soon as the preternatural heat comes on, pain begins to be felt in the head. The pain of the head is often slight at first, and occasionally it remains slight throughout the disease; at other times it is pretty severe. Cases sometimes occur, in which, instead of pain there is only a sense of giddiness, and now and then the uneasy feeling is described as that of lightness; or on the contrary, as that of heaviness, or weight. But whether the feeling be pain, and that pain be slight or severe, or whether it be giddiness or lightness, or heaviness, it indicates a similar condition of the organ and requires a similar treatment.

With the accession of pain of the head there is a manifest increase in the disturbance of the sensorial functions. The inability to think, to compare, to reason, to judge, great as it was at the commencement, is now much greater. Instead of being more dull, there are certain states of the mind which now become more acute and vigilant even than in health. Sensation itself, at this period, is invariably acuter than natural, as is indicated in all the organs of sense. The eye cannot well bear the light: there are few cases in which the full glare of day does not excite uneasiness, while in many the ordinary light of a room cannot be borne: in these cases the opening between the eyelids is frequently observed to be contracted, as if from an involuntary effort to exclude a portion of that stimulus which in health excites no inconvenience, and this state of the eyelids assists in giving to the eye its dull and heavy expression so characteristic of fever. The increase of sensibility in the organ of hearing is equally striking. Sounds which were not noticed during health become acutely and even distressingly sensible, while accustomed noises, such as that of a crowded street, are always painful and often intolerable. The skin, considered as an organ of touch, is in a like morbid state. An impression barely sufficient in the state of health to produce sensation excites the feeling of tenderness, and alternations of temperature which in ordinary states are scarcely perceptible are painful. The senses of taste and smell, on the contrary, are nearly obliterated, owing to the altered condition of the membranes upon which the sensitive nerves are distributed.

From the earliest attack of the disease the sleep is disturbed and unrefreshing; now scarcely any is obtained; the febrile uneasiness will not allow of repose, the patient cannot remain in any position long, incessantly shifting his place, never eluding his pain. At this stage the sense of uneasiness in the limbs, oftentimes the severity of the pain over the whole body, is peculiarly distressing.

With this progressive increase in the affection of the spinal cord and the brain, the derangement in the circulating system is proportionately augmented. The pulse is invariably altered, both in frequency and character, Generally it rises to 90, sometimes to 100; but in this form of fever it seldom exceeds this number; and occasionally it never rises above 80. The stroke of the pulse is usually stronger and fuller than natural, though it commonly retains its softness, and does not impress the finger with that sensation of sharpness which is characteristic of ordinary inflammation. Occasionally, however, a degree of sharpness may be perceived in it, and it is not easily compressed.

The thin white fur which already had begun to appear on the tongue progressively increases in extent and thickness. The colour of the fur usually changes as the disease advances, from a dirty white to an ash colour; but in this form of the disease the tongue always remains moist and never becomes brown. This state of the tongue is almost always accompanied with thirst, but it is never urgent. There is always a loss of appetite. The bowels are generally constipated, and the secretions of the whole alimentary canal are vitiated.

Thus we perceive that the progress of the disease consists in increasing mental and corporeal weakness; increasing pain in the back, loins, and limbs; increasing heat of skin, acceleration of pulse, and general febrile uneasiness, together with the occurrence of pain in the head, and progressive derangement in the functions of secretion and excretion.

The fever in this mild form is now at its height. It remains stationary, or at least with very little change, for an indefinite period, generally for some days. The cerebral affection does not increase beyond what has been described: there are no greater indications of disease in the respiratory organs, and the mucous membrane of the stomach and intestines does not denote any progressive advancement in disease.

In the great majority of patients in whom the symptoms continue thus moderate, the disease disappears about the end of the second week, that is, they are convalescent at that period; but it usually requires eight or ten days longer before they have regained sufficient strength to leave the sick chamber. Sometimes, although there is no greater severity in the symptoms, the disease is more protracted, and the recovery is not complete until the fourth or even the fifth week. Beyond this period it is very rare for this form of the disease to be protracted.

Almost all who are attacked with the malady in this its mildest form, recover: but now and then it happens that the symptoms go on with this degree of moderation until about the end of the second week. Then at the period when it is usual for convalescence to take place there is no perceptible improvement; the patients seem even to grow weaker; they lie more prostrate in the bed, and they are soon incapable of moving; still they complain of no pain or uneasiness, and it is not easy to detect any trace of disease in any organ; yet it is but too evident that they grow worse, and ultimately they sink exhausted. In these cases, on examination after death, it is commonly found that disease has been preying on some vital organ, although its presence could not be detected during life; and this termination of the milder type of fever rarely happens except in aged persons whose constitutions have been enfeebled by previous diseases, or worn out by the various causes which depress and exhaust the powers of life.

With an occasional exception of this kind, the disease in this form always terminates favourably; and the first indication of returning health is remarkably uniform: it is almost always marked by longer and more tranquil sleep. Instead of that restlessness which is so characteristic of fever, and which forms the most distressing part of it, the patient is observed to lie more still, and on waking for the first time from an undisturbed slumber, he often spontaneously says that he feels better. Better he may feel, for his febrile uneasiness is gone; the load that oppressed him is shaken off; he is a new being. The pain of the head and of the limbs is so much diminished, that often he cannot help expressing his thankfulness at the change. The countenance becomes more animated; its natural expression returns; the tongue begins to clean, and after this state of the system has continued for two or three days the appetite returns. While these favourable changes are going on the pulse usually sinks about ten beats below its highest point at the height of the fever; it is not uncommon, however, for it to remain quick during the entire period of convalescence; and for some considerable time it is easily excited on any movement of the body, or any emotion of mind. In some cases, on the contrary, when the attack has been very mild, it sinks considerably below the natural standard, and is intermittent, a sign which has been observed to be attended with a sure and steady convalescence. In the mean time the appetite becomes keener than natural; the strength gradually improves; and in a short time the patient is restored to his usual health and vigour.

The transition of a mild case of fever into a severe one, or the progress of a case severe from the commencement, is accompanied with or depends upon certain changes that take place in certain organs. These changes occur with great regularity; the organs in which they take place are always the same; and the symptoms by which they are denoted are uniform. The organs affected are the spinal cord, the brain, the membranes of both, the mucous membrane of the lungs, and the mucous membranes of the intestines. Other organs become affected in the progress of the malady, but these are the organs which in a greater or less degree are invariably diseased, and which therefore must be considered as the true seats of the structural changes that take place in the regular course of fever. Accordingly in all the severer cases, the symptoms, which are only the external indications and expressions of the successive changes that take place in the internal organs, have their seat either in the head, in the thorax, or in the abdomen. Mixed and blended as these symptoms appear in the different cases which the practitioner is actually called upon to treat, they seem so complex and variable as to bid defiance to any arrangement: when analysed, nothing is more remarkable than their simplicity and their uniformity.

Previous to the changes of structure that take place in the internal organs, it is probable that the different fluids undergo changes no less important. There is indeed a controversy whether the very first change that takes place does not take place in the fluids, and more especially in the blood. There cannot be a question that a morbid change takes place in the blood at a very early period of fever; that that change is different at different stages of the disease; that it is essentially different according to the particular type of fever, and that it is always great in proportion to the severity of the attack. Without entering here into the controversy whether the very first event in the series be a morbid change in the blood, it is manifest that this fluid cannot but become diseased in the progress of fever, because all the processes by which the depuration of the blood is effected are disturbed, and consequently matters which it is the office of these depurating organs to remove from the circulating mass accumulate in it. Moreover there is evidence that the constitution of the blood itself becomes deranged, and that the natural proportions of its essential constituents are subverted. Of course, in a state of the system in which the most important secreting organs are diseased, and in which the fluid that affords the common materials from which the secretions are elaborated is also diseased, the secretions themselves must necessarily become vitiated.

Although these general symptoms are found more or less in all the forms of continued fever, there are some which are regarded as diagnostic of the special forms mentioned above that are of the highest interest. Thus it is found that the two latter forms, typhoid and typhus fevers, are attended with eruptions of the skin as essentially distinct as those of measles and scarlet fever. The eruption in typhoid fever consists of rose-coloured spots which consist of slightly elevated papula or pimples. Their apices are neither acuminated nor flat but invariably rounded, and the bases gradually pass into the level of the surrounding cuticle. These spots disappear completely on pressure, and resume their usual appearance when the pressure is removed. They leave no stain, or pit, or mark behind, and vary in size from a line to a line and a half in diameter. Each papula lasts three or four days, and fresh crops appear every day or two after their first eruption. These spots usually occur on the abdomen, thorax, and back, and only occasionally on the extremities. They usually appear between the seventh and fourteenth day of the disease. (Jenner.)

The rash of typhus fever is distinguished by its mulberry colour. On its first appearance it consists of very slightly elevated spots of a dusky pink colour; each spot is flattened on the surface, irregular in outline, and with no regular margin, but passing gradually into the colour of the skin. It disappears completely on pressure. The spots are of various sizes, and as they grow older do not entirely disappear on pressure, but a stain of the cuticle remains to indicate where they are. This eruption usually appears from the fifth to the eighth day of the disease, and subsides between the fourteenth and twenty-first days. These rashes must not be confounded with "miliary" vesicles, or "sudamina," which sometimes come on in these fevers.

As already indicated in the definitions of these fevers, the typhoid form is attended with a diseased condition of the mucous membrane of the bowels, and the small glands (Peyers) are affected. The symptoms of this disease correspond to this condition. In the early stages abdominal pains and diarrhœa set in, which continue to increase. The belly enlarges as in mesenteric disease, and is resonant on percussion. During the third week of the disease these symptoms become more formidable, and the stools amount to from five to ten in the course of the day. One of the most alarming symptoms is hæmorrhage from the bowels, which occurs towards the end of the attack. This is one of the most formidable symptoms of the disease, although not always attended with fatal results. These symptoms differ very much from those which occur in typhus fever, where there is generally obstinate constipation.

Fever then is a malady in which disease is simultaneously established in the most important organs both of the organic and of the animal life, in the vital fluid which nourishes and stimulates the whole system, in the excretory processes by which the purity of the blood is preserved, and in the secreting processes by which all the different tissues and structures of the body are formed. That it should be always a dangerous disease is therefore not wonderful, but the real extent in which it is the instrument of death is not generally known. Taking together the whole class of febrile diseases, and including the ravages committed by them at all seasons and in all parts of the globe, it is estimated that of the deaths that take place in the human race one half is always produced by these maladies.

With regard to the causes of continued fevers considerable differences of opinion exist. Some writers are inclined to the opinion that there are no specific causes of these forms of disease, but that wherever animal and vegetable matters exist in a state of decomposition, there any one of these diseases may be engendered according to the predisposition of the individual attacked. These writers even deny that there is a poison generated in the body capable of producing a disease in another body. Another body of observers believe that these fevers may originate in external causes, but that they are all of them capable of producing a poison—a materies morbi—which is capable of producing the disease in unaffected individuals. Whilst again, recent investigations seem to point out that typhoid fever is more especially dependent on decomposing animal and vegetable matters, writers supporting this view have called the disease *pythogenic* or drain fever. It is very certain that this form of fever is more liable to break out locally than typhus. It appears, however, to be communicable by the poison generated in the body, but not so much so as typhus.

With regard to typhus fever, it is asserted that it is alone maintained and propagated by a special poison like small pox and scarlet fever. Whatever may be the real causes of these forms of disease, all opinions point to the same means for the prevention of these diseases. Wherever fever has broken out, all sources of corruption should be removed. Drains should be cleansed, and foul deposits of every kind should be got rid of. In order to preserve others, the rooms of the sick should be well *ventilated*, the linen should be washed, and every precaution taken to prevent the discharges from the patient from coming in contact with others. Chlorine and other disinfectants may be advantageously employed. The patient should be *separated* as much as possible from others, and the poison from his body should have every chance of dilution by the free access of pure air.

The *treatment* of these diseases must depend very much on the nature of the case. There is no cutting short the progress of a fever by medicines, and when the disease is progressing favourably little else need be done than to attend to the dietetic wants of the patient.

In typhoid fever the state of the bowels forbid any but the most gentle of purgatives, and that only in the beginning of the disease. A saline treatment so often adopted for typhus is forbidden here. In sinking and exhausted states, ammonia, wine, and brandy are powerful agents for good. Quinine has been strongly recommended in all forms of continued fever by some writers, but Dr. Bennett, of Edinburgh, doubts its value in the fevers of Edinburgh. The various complications of the brain and respiratory system, in the course of the disease, require remedies adapted to meet the special symptoms.

(Sydenham's works; Mead, *Short Discourse concerning Pestilential Contagion, and the Methods to be used to Prevent it*; Sir John Pringle, *Observations on the Nature and Cure of Hospital and Jayl Fevers, in a letter to Dr. Mead: and Observations on the Diseases of the Army*; Clutterbuck *on Fever*; Southwood Smith, *Treatise on Fever*; *Philosophy of Health*; Copland, *Dict. of Practical Medicine*, *Cyclopædia of Practical Medicine*; Watson, *Lectures on the Practice of Physic*; Aitken, *The Science and Practice of Medicine*; Jenner *on the Identity or Non-identity of Typhus or Typhoid Fever*; Jenner *on the Diseases commonly confounded under the term Continued Fevers.*)

FEVER, YELLOW, a disease of frequent occurrence on the eastern and western coasts of America, in the West Indies, in Africa, and in Europe on the southern shores of Spain. The prevalence of this disease in these countries, its great fatality, and the mortality it produces in navies and armies, have attracted much attention towards it both from governments and medical men. This disease has been described under other names, such as typhus icterodes, Bulam fever, bilious remitting fever, vomito negro, vomito prieto, endemial casus, mal de grain, &c. Although this disease has a very distinct history, and can be easily distinguished by the mass of symptoms it presents, yet it is difficult to give in a few words anything like a satisfactory definition. Dr. Gillkrest, one of the most recent writers on this subject, gives the following definition: a disease in which "yellowness of the skin, partial or general, and towards the fatal termination, vomiting of a black or dark brown fluid, are frequent though by no means constant occurrences." Such a definition would be of little use for distinguishing the disease, and perhaps after all it will be found that yellow fever is only a modification, under peculiar circumstances, of some primary form of disease in which all fevers originate. It is certain that this disease has many symptoms in common with other fevers, and that it assumes the types of the common, continued, remittent, and intermittent fevers.

It has only been within a comparatively recent period that this disease has attracted much exclusive attention, and on this account some writers regard this disease as one altogether of modern origin, and fix the date of its generation during the latter part of the eighteenth century. But although no accurate account of this disease as distinguished from other fevers exists, previous to its appearance in the island of Granada, in 1793, yet there can be no doubt that the records of the occurrence of destructive fevers in those districts in which the yellow fever now occurs, refer to the same disease.

The attack of yellow fever is mostly preceded by well-marked premonitory symptoms. For two or three days previous to the attack there is a depression of spirits and an unnatural inactivity without any sufficient accountable cause. There is sometimes nausea, with a creeping chilliness, and pains in the loins, back, arms, legs, and head. The eyes are suffused, dull, and heavy, and the sight is dim and sometimes double. There is often slight confusion of mind and a kind of drowsy restlessness. The appetite is bad, the taste is perverted, and the bowels are either confined or relaxed. The skin is in some cases permanently dry, or there may be sweating after slight flushes of heat. The pulse varies considerably; it may be small, quick, and irregular, or soft and full. Such symptoms do not however always occur, and sometimes the patient is seized immediately with a shivering, the indication of the near approach of the worst symptoms. Sometimes during this premonitory stage there may exist a yellowness of the eyes and of the skin, and also a vomiting of bilious matter.

The commencement of the febrile attack mostly takes place at night: after the shivering, a state of general excitement takes place, which sometimes increases to a very distressing and unmanageable extent. Pains occur in the head, in the eyeballs, in the back and loins, and cramps in the gastrocnemic muscles. The patient prefers the recumbent position and lies upon his back, but is in a state of great restlessness, frequently throwing his arms about, more especially above his head. The face is usually flushed, sometimes of a crimson hue, and occasionally swollen so as to appear bloated and heavy. The eye has a heavy drunken appearance, is injected, swollen, and moistened with tears; the pupil is generally permanently dilated, and the balls seem protruded as if they would start from their sockets. The skin is in most cases flushed, dry, and warmer than natural. The pulse is accelerated, soft, full, and compressible; in some cases, however, it is unusually slow, and under these circumstances the skin is unnaturally cool. The tongue is swollen and coated with a white mucous paste. Vomiting does not often occur in this stage. The bowels are frequently more or less constipated, but easily acted on. The intellectual functions are more or less deranged. These symptoms last for twelve or thirteen hours, when the second stage may be said to commence. The general excitement now gives way to depression. The countenance becomes deeply expressive of anxiety. The congested state of the eye begins to yield, and in its place a slight yellow tinge is observed. This goes on increasing till it extends down the alæ of the nose and around the mouth. As the disease advances, in most cases the yellow tinge spreads itself over the whole skin, giving to the whole body, according to the complexion or temperament, various colours, from a pale lemon to deep orange or saffron colour. The pulse becomes slightly lessened in frequency. The coating on the tongue becomes yellow, and this organ towards its roof and at the edges and tips has a clean and dry red appearance. The stomach now becomes irritable and painful on pressure. Food is immediately rejected. There is a distressing sensation of internal heat. The vomiting is sudden, and not accompanied with any severe retching. The matters vomited are generally ingesta and a clear fluid, and only sometimes is bile discharged. The alvine secretions are mostly natural. The urine is diminished in quantity, and very yellow. There is frequent sighing of a deep and prolonged character. In malignant cases the breath exhaled has an acid odour. The intellectual functions are much affected, and the patient is in a state of low muttering delirium, or comatose. Sometimes petechiæ and miliary vesicles occur in this stage. In this state the patient may remain from two to seven days. The countenance then becomes more collapsed, the eye loses its full and prominent character, dark-coloured blotches and petechiæ occur on the body, the pulse becomes small and thready, the tongue loses its coating and becomes bright red, thirst becomes urgent, and there is lastly the vomiting of a dark and mucous-looking fluid, which has been called the "black vomit," and has in fact given the name sometimes to this disease. This symptom, however, does not always occur. As death approaches the exhaustion becomes greater, the respiration is hurried and noisy, the surface and extremities become cold, and covered with a general clammy perspiration. In some the last moments are marked with great pain and strong convulsions, whilst in others death seems to come upon the patient unawares.

These general symptoms are by no means presented in every case, some having been constantly observed by one medical writer, whilst others have never witnessed them at all. Amongst the forms which this disease assumes, three are mentioned by some writers as pointing out important differences in the character of the disease: these are called inflammatory, adynamic, and malignant. The *inflammatory* occurs in full plethoric habits, and the whole of the symptoms indicate a greater amount of excitement and activity, and the disease proceeds to a fatal termination sooner. The *adynamic* variety occurs in those who have deficient animal vigour. In this form of the disease the pulse is slow, the skin cold and clammy, no resistance appears to be made to the progress of the disease, and the patient sinks in the course of four or five days. The *malignant* form is the worst of all: from the first the patient seems attacked with death; all the symptoms are low from the beginning, and no reaction is established. Persons seldom recover from this state, and many die during the first twenty-four hours of the attack.

The nature and origin of the black matter which is so often vomited in cases of yellow fever has been the subject of much investigation. The most correct view is probably that of Dr. Fordyce, who considered that it was identical with the incrustation of the tongue, gums, and lips found generally in violent fevers, and that probably this is an exudation thrown out from the surface of the stomach, or even from the duodenum and jejunum. When collected and given to animals it produced no bad effect upon them, and an atmosphere impregnated with its exhalations does not appear to be injurious. Under the microscope it has the appearance of minute scales of smoked mica, being of a dark brown or red colour. It is probably nothing more than the globules of blood broken down, which have oozed through the surface of the mucous membrane, instead of the ordinary secretion, and perhaps under the influence of the violent vomiting. It may frequently be mixed with bile, but it does not appear in the majority of cases to have the character of bile at all.

As it is difficult to give a definition of yellow fever, so is it difficult to give any rules by which it may be distinguished in individual cases from other diseases. Its occurring, however, generally in several individuals at the same time, soon leads to the development of the group of symptoms which we have described, and by which it may be distinguished from allied diseases.

The mortality from this disease is always very considerable. It is usually much greater at the commencement of the epidemic than it is at subsequent periods. In some instances all the cases occurring for the first few days after the breaking out of the fever have proved fatal. Sometimes however the disease is very mild, and but few fatal cases occur. The mortality is generally greatest amongst the young and robust, and this will perhaps account for its fatality amongst soldiers and seamen. This fever has been regarded as peculiar to places between 40° N. lat. and 20° S., and requires a climate in which the mean summer range is not less than 75°, or, according to some authors, 80°. More temperate climates are not, however, free from its attacks. It appeared at Lisbon in 1857. One-twelfth of the whole population was attacked with the disease, and of these one-third died. The total of the deaths in the whole population was between five and six thousand. From the histories of this attack in Europe, we may learn that none of our towns have an immunity from this disease, and that it is only by carrying out those sanitary measures which are now so extensively adopted, that we can expect to be free from such a visitation of this disease as at Lisbon.

The morbid appearances of the body after death do not throw any light on the nature of this disease. In the head the dura mater is found studded with dark-coloured spots; under the arachnoid is frequently accumulated a yellowish serosity. The lesions in the chest are not remarkable. The stomach is generally distended with air, its mucous surface is occasionally suffused with blood, and its vessels are generally gorged with blood. The orifices of numerous canals may be seen, from which by slight pressure oozes a fluid which appears to be the "black vomit." The small intestines participate in some measure in the lesions of the stomach. The liver is sometimes engorged with blood, and sometimes it is hard and dry. The spleen is usually increased in volume and softened.

In the treatment of yellow fever much difference of practice has prevailed, according to the opinions of those called upon to treat the disease; and unfortunately that kind of evidence does not at present exist on which we could rely with regard to the value of any particular course of treatment. Under these circumstances the judicious practitioner will act on general principles, and treat whatever cases come before him according to the symptoms they present. As is mostly the case in the treatment of fevers which in their course exhibit both active and low symptoms, two very different plans of treatment have been recommended; the one antiphlogistic, the other stimulant. Without discussing the respective merits of these plans of treatment, it may be stated that both may be rendered necessary in different stages of the disease.

Amongst antiphlogistic remedies, blood-letting has been highly commended, but it is not so frequently employed as formerly. The next remedy in importance is mercury. Some of the best writers on yellow fever, and those who have had the largest experience, consider mercury as their sheet-anchor in this disease. It should be administered in doses of sufficient quantity to affect speedily the mouth. Many practitioners who use this remedy do not employ blood-letting as an ordinary remedy, but only in those cases in which the inflammatory symptoms preponderate. In addition to these means, purgatives, emetics, antimonials, and cold affusion have had their advocates. These remedies are however all of them adapted more to particular states of the system than to the disease of yellow fever, and should be administered according as circumstances arise which may indicate their necessity. In cases where the disease assumes a remittent form, quinine may be administered with advantage. Dr. Stevens particularly insists on the administration of saline medicines in yellow fever, to which there is no objection, provided the stomach will retain them, and they probably have a beneficial effect on the system according to his theory.

Of all the questions connected with yellow fever, perhaps that which regards its *cause* has been discussed with the most zeal and bitterness. We cannot here go into any details of this discussion, but the great point in dispute is the contagiousness of this disease. Many of the early writers on yellow fever concluded that it was contagious, and on this account persons who have been exposed to its influence are obliged to submit to the most rigid quarantine regulations. But whilst there is much evidence to prove that this disease is communicable by a morbific matter generated in the human system in a state of disease, there can be no doubt that it has in most cases a local origin. Many recent writers have supposed that the local cause of this disease was to be found in the temperature and other atmospheric phenomena in the district visited by the disease; but this cause is too general to account for the exceeding local character of the disease in many instances. Cases are recorded in which the inhabitants of particular parts of a town, the one side of a street, or even one room of a house, have been attacked, whilst all others have escaped. The true theory of the production of these diseases is probably to be found in the fact that they originate in decomposing animal and vegetable matter, and afterwards become susceptible of communication from one individual to another by a poison generated in the body. The history of the development of the disease at Lisbon is remarkably confirmatory of these two points.

(*Library of Practical Medicine*, article "Yellow Fever," by Dr. Shapter; *Cyclopædia of Practical Medicine*, article "Yellow Fever," by Dr. Gillkrest; Bancroft, *An Essay on the Disease called Yellow Fever;* Dr. R. D. Lyons, *Report on the Yellow Fever at Lisbon, in* 1857.)

FIBRIN. Fibrin is an important constituent of animal and vegetable organisms. In animals it occurs dissolved in the blood, to the extent of 2½ parts in 1000, and is the principle of which muscle and the fibrous tissue of flesh are built up; indeed, these parts are usually looked upon as consisting of fibrin itself, though altered in several respects from the condition in which it exists dissolved in blood: the name also is derived from the fibrous character of these tissues, particularly from the bundles of fibres composing the muscles.

Fibrin has already been shortly noticed under the article ALBUMEN, as forming, with a few other closely allied substances, that interesting class of bodies known as the protein or albuminoid group; they are sanguigenous or blood-forming matters, and hence are usually termed *plastic materials of nutrition*, to distinguish them from those constituents of food that serve to maintain the function of respiration only, and hence called *respiratory* elements. The lean part of meat contains large quantities of fibrin and other plastic materials, obtained in the first instance from certain parts of plants, and stored up, as it were, in a concentrated form for the use of man; while the fat of meat, together with such respiratory principles as sugar, starch, &c., serve to keep up the heat of the body by the gradual oxidation or slow burning they undergo during the process of respiration.

Fibrin undergoes spontaneous coagulation very soon after its removal from the living structure. Thus, blood freshly drawn from an animal is tolerably fluid, but after standing a short time becomes transformed into a gelatinous mass or clot; this is owing to the alteration of the fibrin from the liquid to the solid state. Again, the recently expressed juice of vegetables soon deposits a precipitate from a similar cause. This property of spontaneous coagulation is alone possessed by fibrin, and serves therefore to distinguish it from its congeners, albumen and casein.

1. *Animal fibrin* is most readily obtained from blood; it is, however, contained in some quantity in chyle and in lymph. To obtain it, fresh blood is briskly whipped with a bundle of twigs, when, after a short time, the fibrin, in the form of short elastic strings, is found adhering to the twigs. It is still contaminated with some of the red colouring matter of the blood, but by maceration in, and patient washing with water, it is finally obtained quite colourless. When dried, this fibrin has a horny appearance, is hard, opaque, of a grayish or yellowish colour, and without taste or odour. It is insoluble in cold water, alcohol, or ether, but by long contact with boiling water is to a certain extent decomposed. Heated with water in a sealed tube to 300° Fahr. it entirely dissolves, forming a solution precipitable by acids, and much resembling the solution of albumen obtained under similar circumstances. A somewhat analogous solution occurs if the fibrin, in contact with a little water, is exposed to the air for some time; but in this latter case a considerable amount of decomposition occurs, and sulphide of ammonium, butyric acid, leucin, and other principles are generated. Animal fibrin is soluble in moderately dilute solutions of the fixed caustic alkalies, yielding a liquid possessing the properties of albuminate of the base; acetic or tribasic phosphoric acids precipitate the fibrin, but in excess redissolve it. The fibrin may also be made to combine with other metallic oxides; the resulting compounds are, however, almost identical with the albuminates. Digested in strong sulphuric acid, fibrin swells up, and by aid of a gentle heat entirely dissolves. Hot nitric acid also dissolves it, the solution containing *xanthoproteic acid*, an acid that is also produced under similar circumstances from albumen and casein. Hot concentrated hydrochloric acid decomposes fibrin into leucin, tyrosin, and other matters.

Epidermose is the name given by M. Bouchardat to that part of the fibrin obtained from blood, that is not soluble in dilute hydrochloric acid; that chemist considering it to be identical with a substance which forms the base of the epidermis: while to the portion of the fibrin that is dissolved by the dilute acid he gives the name *albuminose*. According to Liebig, however, blood-fibrin swells up in dilute hydrochloric acid, but does not form a true solution at all; while muscle-fibrin dissolves more or less completely in that menstruum.

Fibrin has been examined and analysed by several chemists with tolerably uniform results, but though its composition has been thus ascertained, its true constitution is not at present satisfactorily established. Mulder, who has paid considerable attention to this and the analogous azoto-sulphurised principles, gives the following as the percentage composition of fibrin:—

Carbon	52·7
Hydrogen	6·9
Nitrogen	15·4
Oxygen	23·5
Sulphur	1·2
Phosphorus	0·3
	100·0

The combustion of fibrin is always attended with a residue or ash, containing phosphate of lime and a little phosphate of magnesia.

2. *Vegetable fibrin* is frequently met with in pharmaceutical operations on the newly-expressed juice of fresh vegetables, nearly all such liquors depositing coagulated fibrin on standing for a short time. Like animal fibrin it does not admit of being examined in the liquid state, but in the solid form is obtained in what is generally considered to be a more or less pure state, from the so-called gluten of wheat flour. Boiling alcohol dissolves a considerable portion (true gluten) of this gluten, and what remains undissolved after repeated ebullition with the alcohol and with ether, is vegetable fibrin. Its ultimate chemical composition is very much the same as that of animal fibrin. In contact with moisture it is slowly decomposed. A farther description of its characters and properties is unnecessary, inasmuch as, so far as those characters are known, it would be but a reiteration of what has already been detailed above under *Animal Fibrin*.

FIBRÖIN. This name has been applied by Mulder to the nitrogenous substance composing the fibre of silk. It is purified by treating raw silk successively by boiling water, alcohol, ether, and acetic acid. It then contains:—

Carbon	48·53
Hydrogen	6·50
Nitrogen	17·35

FIBULA, a term used among the Romans for the brooch or buckle with which their vests were usually fastened. It is derived from *figo*, "to fix," and the most ancient form of the word is supposed to have been *figibula*. These fastenings were made in very great variety, both as to material and form, and were sometimes decorated with engraved stones or gems, for like the modern brooches, fibulæ were employed for ornament as well as use. Fibulæ of gold were often used as presents. The most common were made of brass or iron. The most usual was that of a circular ring or disc of metal, with a pin moving on a hinge, and passing across the centre of the circle. Fibulæ were used by the Roman women for fastening the inner and outer garment (*indutus* and *amictus*), and the scarf or cloak; sometimes indeed they not only wore them for these purposes on their breast and one or both shoulders, but in the later and more luxurious ages as ornaments down their sleeves, and for fastening their tunics above the knee. Count Caylus, in his 'Recueil,' pl. 110, fig. 4, has engraved a fibula which served the double purpose of a fastening to the garment and a key. The richly ornamented buckles used by the Romans for fastening the belt and girdle were also called *fibulæ*. *Fibula* was a term likewise applied by the ancients to the iron brace or band used for joining or fastening beams, mentioned by Cæsar ('De Bello Gall.,' l. iv., c. 17) and described by Vitruvius (l. i., c. 5). The *fibula chirurgica* was an instrument used by surgeons for drawing the lips of a wound together, noticed by Pitiscus, in his 'Lexicon,' p. 778, who also mentions the *fibula gymnastica*, sive *theatralis*, "quæ cantoribus et comœdis inserviebat," particularly described by Celsus, and several times alluded to by Juvenal and Martial. This was a ring of light workmanship.

FICHTELITE, a fusible volatile crystalline substance, found in the submerged pine-trees of the Fichtel-gebirge. Its composition is $C_{20}H_{20}$.

FICTION. [NOVEL; ROMANCE.]

FICTIONS (in Law) have been somewhat quaintly defined to be "those things that have no real essence in their own body, but are so acknowledged and accepted in law for some especial purpose." These especial purposes are various. The law, it is said (by which we must understand those who for the time are the interpreters of it), shall never make any fiction but for necessity, and in avoidance of a mischief. (Coke's 'Rep.,' iii. 30.) This is as much as to say that those who interpret the law will, in order to avoid a special hardship, or remove some unexpected difficulty not provided for by the law, resort to a fiction; that is, they will imagine something to be which is not. It is said that such fictions have always a good end in view; that is, an end considered good by those who make or maintain the fictions. It was wisely said, that fictions of law must not be of a thing impossible; but the reason is rather curious, "for the law imitates nature." If we object to the soundness of the reason in the instance last mentioned, we cannot but approve of the following rule as to fictions: that a man could never be subject to the penalty of a statute by a fiction of law. The law, it was said, would also make fictions in order to avoid absurdity; but this could hardly have been said in earnest.

Blackstone shows by what fiction the Court of Queen's Bench originally held pleas of all personal actions: "It being surmised that the defendant is arrested for a supposed trespass which he never has in reality committed; and being thus in the custody of the marshal of the court, the plaintiff is at liberty to proceed against him for any other personal injury: which surmise, of being in the marshal's custody, the defendant is not at liberty to dispute." Such liberty of disputing the fiction would clearly spoil the whole business, and was therefore as necessarily disallowed as the fiction was allowed. (See also the fictions formerly resorted to in EJECTMENT, and in the Court of EXCHEQUER.) Of the same kind is the fiction mentioned by Blackstone, by which a contract made at sea is feigned to be made at the Royal Exchange, or other inland place, in order to draw the cognisance of the suit from the courts of Admiralty to those of Westminster Hall. "Such fictions," as Blackstone remarks, "are adopted and encouraged in the Roman law: a son killed in battle is supposed to live for ever for the benefit of his parents; and by the fiction of *postliminium* and the *lex Cornelia*, captives, when freed from bondage, were held to have never been prisoners; and such as died in captivity were supposed to have died in their own country."

Fictions in law, though often ridiculous enough, have generally had their origin in some defect in the existing laws or course of procedure, and have pointed out in what respects the judges or interpreters of law, and, as we may suppose, general opinion also, under the influence of which judges must to some extent be, have felt that change was necessary. Many fictions, so far from being injurious, have been beneficial; but it must be remarked that they are the indications of a rude state of social organisation, and must gradually disappear with the improvement of the institutions of society; for their existence supposes a defect which it is the business of legislation to remedy.

FIDDLE. [VIOLIN.]

FIDEI COMMISS. According to German civil law, the fidei commiss is intimately connected with the law of inheritance among the nobility, being the regulation according to which the whole or part of a family property is enjoyed by a certain member of the family, on the condition of leaving it unimpaired to the person pointed out by the particular family arrangement; either to the first-born male, when it is called *majorat;* or to the last-born male, when it is called *minorat;* or to the oldest member of the family without regard to direct descent, when it is called *seniorat.* Like the English law of entail, the object of this institution is to render the family property inalienable; it may however be mortgaged, but this is merely a temporary sequestration of the revenues which are applied to cancelling the debt. In modern times, this institution, like many others, has been abolished in some parts of Germany, partly by the introduction of the French law, as in the Rhenish provinces, and partly by the amalgamation of the former German civil law with the Code Napoleon, as in Bavaria. In the north of Germany, however, where the ancient Saxon law was prevalent, as in Hanover, Saxony, and other countries, it has been maintained, and is still in force.

FIDEICOMMISSUM, or a transaction dependent upon honour and probity (*pudor*) rather than legal sanction (*vinculum juris*), I. 2. 23, 1, in the Roman law, is something given by will or codicil, not directly to the person beneficially interested in it, but to some other person, with a request that he will transfer it to the party for whom it was intended. The person thus intrusted was called Heres Fiduciarius; and the person for whom it was intended Heres Fideicommissarius. It was necessary that an heir (*heres* in the Roman sense) should be named, or no property could be transmitted to the fideicommissarius; for, without the "institutio heredis," the will itself was invalid, but a fideicommissum might be left by an intestate in the manner prescribed in the Institutes 2. 23, 10. (Gaius, ii., 248, &c.) Originally it entirely depended on the good faith of the trustee (*fiduciarius*) whether he performed the will of the testator or not.

The origin of these fideicommissa probably was in a desire to evade the strictness of the old civil law; as we see in the case of Q. P. Rufus (Val. Max., iv. 2, 7), who, being an exile, was incapacitated from taking a gift under the will of a Roman citizen, but yet could claim it from his mother, to whom it had been given in trust for him. (See also Cic. de Fin., ii. 18, § 58; and Quintil. Declam., 325.) Gaius, however (Comm., ii. 285), attributes the origin of these testamentary injunctions to the capacity of the peregrini to receive bequests in this way; but he gives no account of the time when, or the mode in which, such capacity was obtained. In the time of Augustus the rights of the fideicommissarius became legally established by the emperor giving the consuls jurisdiction in such matters. Afterwards pretors were expressly appointed, under the name of Prætores Fideicommissarii, to take cognizance of such trusts, but the consuls still retained their jurisdiction also. (I. 2. 23, 1.) In the provinces the governors (*præsides*) took cognizance of fideicommissa. (Ulpian, 'Frag.,' 25, 12.) Fideicommissa, or trusts of specific things, became gradually assimilated as to their qualities and incidents to legacies. The following remarks apply to fideicommissa where the whole inheritance (*hereditas* in the Roman sense), or a determinate part, was given to a trustee in trust.

By the old Roman law, the *heres* who was the successor in universum jus defuncti, on taking possession of the testator's property, became liable to all his debts and obligations, and consequently those who only took the property as trustees (*heredes fiduciarii*) often refused to encumber themselves with a burden from which they could derive no advantage, and might sustain great loss. To remedy this inconvenience, it was enacted by the Senatusconsultum Trebellianum, passed in the time of Nero, that when the trustee had given up the property to the fideicommissarius (*cestui que trust* of the English law), all right of actions by or against the trustee, in respect of the property, should be transferred to the cestui que trust. (I. 2. 23, 4 & 6.)

If the trustee refused to accept the inheritance, the pretor, on the petition of the cestui que trust, could compel him under the Senatusconsultum Pegasianum, passed in the time of Vespasian, to accept and to transfer the property to his cestui que trust, who took it with all its burdens. No particular form was requisite in order to effect this transfer. (I. 2. 3, 5, and 6.)

By the Senatusconsultum Trebellianum, if the heres was required to transfer not more than three-fourths of the inheritance to the cestui que trust, the two parties were liable to all suits and burdens in respect of the property according to their several shares. If he was required to transfer more than three-fourths or the whole, the S. Pegasianum allowed him to retain one-fourth, as the Falcidian law did in the case of legacies. If the heres let himself be compelled to accept the trust under the S. Pegasianum, he lost his one-fourth. (D. 36, 1.)

The cestui que trust was himself sometimes only a trustee for others, and in this case never had the benefit of the one-fourth: the same was the case if a legatee had to transfer a legacy to another.

In his remarks upon the origin of Uses and Trusts in England, Mr. Spence has given a short but clear and able sketch of the introduction of fideicommissa at Rome; and in a note to that part of his text which treats of the technical terms necessary to constitute a fideicommissum, he states "that these forms of expression are constantly referred to as guides to the Court of Chancery on questions of the like nature." Vide int. al. "Knight *v.* Knight," 3 Beavan, 161 & 172.

(Spence's *Equitable Jurisdiction of the Court of Chancery*, vol. i., p. 438.)

FIEF. [FEUDAL SYSTEM.]

FIELD (in Magnetism), is the space between the two poles of a magnet, where the two forces mutually re-act. [MAGNETISM.]

FIELD (in Optics), is the actual magnitude of the space that can be presented at once to the eye of the observer; it must vary with the magnifying power, and is large in proportion as this is small. With the lowest class of powers it is a circular space not exceeding the eighth or the tenth of an inch in diameter. With the power of 500, the field is only 1-70th of an inch in diameter. [MICROSCOPE.]

FIELD-GLASS. Between the object-glass and the eye-glass of a microscope there is usually interposed a convex lens, which receiving the diverging rays from the former before they form an image, has the effect of contracting the dimensions of the image and increasing its brightness, so that it is not too large or indistinct to be seen at once by means of the eye-glass. This interposed lens is called the *field-lens,* and that portion of the image which can be seen at once with the eye-glass is called the *field of view* of the microscope. [EYE-GLASS; FIELD; MICROSCOPE.]

FIELD-MARSHAL, a military dignity conferred on generals and commanders of armies for distinguished services, and also as a compliment to persons of high personal rank, as princes of the blood royal.

It has been supposed that the term marshal is derived from *Martis Seneschallus,* but it is more probable that it came from the Saxon words *mar,* or *marach,* a horse, and *scalck,* a servant; and it appears to have designated the person who had the care of a certain number of horses in the royal stables. In the Teutonic laws such a person is called *maris calcus,* and the fine for his murder is particularly specified.

The earl-marshal of England had originally the chief command of the army; and history records the names of two noblemen, De Montmorency and Fitzosborne, on whom the title was conferred by William the Conqueror.

The office was by Henry VIII. made hereditary in the family of the duke of Norfolk; but it is probable that it had before that time ceased to be connected with the military service; for from the 'Anecdotes of the Howard Family,' we learn that while another person held the post of earl-marshal, Sir Robert Willoughby Lord Brooke was appointed by Henry VII. to be marshal of the army.

The title of Maréchal de France appears to have become a military dignity in that country in the time of Philip Augustus; and, according to Père Daniel, the first person who held it was Henry Clement, the commander of the French army at the conquest of Anjou, in 1204. Originally there was but one Maréchal de France, but, in 1270, when the king, Saint Louis, went on his expedition to Africa, a second was appointed. Francis I. added a third; and the number has since been greatly increased.

The maréchaux de camp, in the old French service, were charged with the duty of arranging the encampment and providing subsistence for the troops; and in action they had the command of the wings, or of the reserve of an army, under the general-in-chief. From the title borne by this class of general officers is derived that of feld-marschall in the German armies; and from the latter title has arisen that which corresponds to it in the British service.

The number of field-marshals in the British army is at present four.

FIELD OF VIEW. [TELESCOPE.]

FI'ERI FA'CIAS, a judicial writ of execution issued on a judgment obtained in a personal action in the queen's courts. It is directed against the goods and chattels of the defendant, and is called a writ of *fieri facias,* from the words in it whereby the sheriff is commanded "quod fieri facias de bonis," &c., that he cause to be made of the goods and chattels of the defendant the debt or sum required. [EXECUTION.] It lies against privileged persons, as peers, &c., as well as other persons, and also against executors and administrators, so far as regards the goods of the deceased.

This writ, like all other writs of execution, being founded upon the judgment, must strictly conform to, and be warranted by, the terms of the judgment, or it will be void. By virtue of this writ, the sheriff may sell the goods and chattels of the defendant till he has raised enough to satisfy the judgment and costs, as well of the suit as of the execution; and also to satisfy any rent due to the landlord of the premises where the goods may be at the time of the taking, not exceeding one year's rent in the whole. If the judgment is not satisfied by the sale of the goods of the defendant, the plaintiff may have a capias ad satisfaciendum for the residue. [CAPIAS.]

The sheriff is not justified in breaking open any outer doors to execute this writ, but having peaceably obtained entrance, he may break open any inner door belonging to the defendant in order to obtain possession of the goods. The clothes which the defendant actually has on or in wearing cannot be taken, and royal palaces are privileged against the sheriff's intrusion for the purpose of levying upon the goods of a resident therein.

Formerly it was necessary that writs of execution should bear teste or date, and be returnable in term time; but now, by stat. 3 & 4 William IV., c. 67, they may be tested, that is, dated on the day when issued, whether in term time or vacation, and may be made returnable immediately after the execution thereof.

If a fieri facias is issued against a clergyman, and the sheriff returns that he has no goods upon which the judgment can be levied, but that the defendant is a beneficed clerk not having any lay fee, the plaintiff may sue out a "fieri facias de bonis ecclesiasticis," which is directed to the bishop of the diocese, or to the archbishop during the vacancy of the bishop's see, commanding him to make of the ecclesiastical goods and chattels of the defendant within his diocese the sum therein mentioned. It is tested and made returnable exactly in the same manner as a common fieri facias, and is executed by means of a sequestration issued by the registrar of the diocese. [SEQUESTRATION.] ('Bl. Com.' v. iii. Dr. Kerr's Edition; Archbold, Q. B. Pract. vol. ii.)

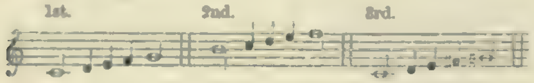
FIFE, a very small flute with never more than one key, and seldom that, giving acute piercing sounds, and used, together with the side drum, for military purposes, in marching, &c. It is an octave higher than the flute, and in compass comprises two octaves. Fifes are of three sizes, named by the letters A, B, and C. The first is the lowest; the last, which is that in common use, is the highest.

FIFTEENTH, in Music, is the interval of the double octave.

The *fifteenth stop* in organs is a range of metallic pipes, tuned two octaves higher than the diapasons.

FIFTH, an interval in music, and the most perfect of concords, the octave excepted. Its ratio is 3 : 2. [CONCORD; HARMONY.]

There are three kinds of Fifths; the *Perfect Fifth*, the *Flat* or *Diminished Fifth* (called also the *Imperfect Fifth*), and the *Extreme Sharp* or *Superfluous Fifth*. The first (C, G) is composed of three whole tones and a semitone; the second (B, F) of two whole tones and two semitones; the third (C, G ♯) of four whole tones. Ex. :—



FIFTH MONARCHY MEN, a sect of religionists, whose distinguishing tenet was a belief in the coming of a fifth universal monarchy, of which Jesus Christ was to be the head, while the saints, under his personal sovereignty, should possess the earth. They appeared in England towards the close of the Protectorate; and in 1660, a few months after the Restoration, they broke out into a serious tumult in London under their leader Venner, in which many of them lost their lives, some being killed by the military, and others afterwards executed. Several Fifth Monarchy Men also suffered death in 1662, on a charge (most probably unfounded) of having conspired to kill the king and the Duke of York, to seize the Tower, &c. They are the same who were sometimes called Millennarians, their notion being that the reign of Christ upon earth was to last for a thousand years. They seem, also, from the extravagance and violence of conduct into which they occasionally broke out, to have been confounded in the popular imagination with the old Anabaptists of Münster. [ANABAPTISTS.]

FIG, the *Ficus carica* of botanists, is a small tree, with rough, lobed, deciduous leaves, naturally inhabiting the temperate parts of Asia, and now commonly cultivated in Europe for the sake of its fruit.

In the fertile islands of the Mediterranean, in Spain, Italy, and Greece, and even so far north as the south of France, the fruit is so well ripened as to form a valuable article of exportation in a dried state. A thousand tons are annually imported into Great Britain alone. The fruit is grown with some success even in the southern and milder parts of England, but it is seldom found in the northern parts or in Scotland, except under glass. It is only as an object of cultivation in this country that we have to consider it in this place.

The nomenclature of figs is in a greater state of confusion than that of most other fruits, and the descriptions of them generally so imperfect that the same kind is grown in different parts of the country under many different names; an account of their synonyms, as far as they have been determined, will be found in the Horticultural Society's Fruit Catalogue, ed. 2.

The following is a list of the best sorts :—

Black Provence.
Large Blue.
Brunswick.
Blue Burgundy.
Early White.
Large white Genoa.
Hamburg Brown.
Black Ischia.
Brown Ischia.
Green Ischia.
White Ischia.
Yellow Ischia.
Lee's Perpetual.
White Malta.
Large Black Naples.
White Naples.
Small Green.
Brown Turkey.

The best sorts for forcing are :—

The Ashridge Forcing.
Figue Blanche.
Early Forcing.
Marseilles.
Nerii. (This excellent sort will not bear a high temperature.)
Pregussata.

The following kinds are recommended as a selection for a small garden, in the southern and midland counties of England :—

Black Ischia.
Brown Turkey.
Brunswick.
White Malta.
Large white Genoa.
Marseilles.
Small early White.

The following sorts have been recommended for a succession from August to October in the south of England :—

Brown Ischia . .	ripens in the middle of August.
Large white Genoa . .	„ end of August.
Green Ischia . .	„ beginning of Sept.
Murrey, or Brown Naples	„ middle of Sept.
Ford's Seedling . .	„ end of Sept.
Black Provence . .	„ beginning of Oct.
Yellow Ischia . . .	„ middle of Oct.
Gentile	„ end of Oct.

The most approved methods of propagating fig trees are either by layers or cuttings, and the former method is generally preferred, because the plants at the end of the season are stronger and more fit to be planted out where they are intended to grow. Trees raised from layers generally come into bearing the second year. Grafting succeeds upon these trees as well as upon any other, but it is almost unnecessary and seldom practised. Before the trees are planted the ground should be well drained, and made from two feet and a half to three feet deep, with a mixture of good friable loam and decayed dung. Miller remarks, that "fig-trees bear the greatest quantity of well-flavoured fruit when growing upon chalky land where there has been a foot or more of a gentle loamy soil on the top."

It was generally believed until a few years back that pruning was injurious to the fig, but experience shows this opinion to be unfounded, and that it is as tractable in this respect as any other tree.

The object to be always kept in view is to have constantly a supply of fruit-bearing shoots, and for this purpose the old wood should be gradually cut away, and the young introduced to fill the space thus created. Since the climate of this country will not admit of two crops in one year being brought to maturity, as in other countries more favourable to its growth, the fruit formed after midsummer should be removed, in order to strengthen the tree and render it more productive the following season.

Several modes of training are practised and recommended: some gardeners recommend the fan system, others the horizontal; but this must depend entirely upon the growth of the tree: if it be luxuriant, the latter may be practised; if not, the former will answer better; as the more perpendicular a tree is trained the stronger it grows, and a contrary effect is produced by horizontal training. Mr. Knight recommends the branches to be trained in a downward direction as well as horizontally, and says, "The young wood ceases to elongate very early in the season, and thence acquires perfect maturity, and by being trained close to the wall it is not so liable to be injured by frost."

In many parts of the continent where the winter is very cold, but where the summer heat is sufficient to ripen the fig, as a standard, the trees are planted in rows and bent down near the ground in winter, and then covered with leaves, which protect them from very severe frosts. Wall trees are unnailed and bent down on each side to within a few feet of the ground, and then protected in the same way as standards.

In this country the common practice is to stick yews, spruce-fir branches, or fern leaves amongst the branches of the fig upon the wall. Where anything can be used for protection which can conveniently be removed in fine mild weather, it will be found of greater utility than having the branches covered up from the commencement of winter until the end of spring.

When the trees are planted in the border of a hot-house for the purpose of being forced, they are commonly trained to trellises; and the treatment is precisely the same as that recommended for open walls. After the fruiting season the border must be kept perfectly dry, in order that the trees may enjoy a season of rest; but a plentiful supply of water is given when they are in a state of growth.

Those who have not a house which can be appropriated entirely to the forcing of figs may nevertheless obtain good crops by planting the trees in pots and forcing them in a cherry-house, peach-house, or vinery. The time for beginning to force is from December to February, according as the fruit is wanted; and the temperature should be gradually increased from 50° to 65° or 70° Fahr. Some also approve of a bottom heat, and recommend the pots to be plunged in a bed of leaves or tan.

The fig-tree is very apt to throw off its fruit before it ripens, and various methods have been suggested to prevent this. In the Levant, to insure a crop, a process termed caprification is resorted to, which consists in placing among the cultivated figs branches of the wild fig, in which a kind of Cynips abounds. This insect, issuing from the wild fruit, enters the others, brushing about the pollen in the inside, and so fertilising the fruit. Or those figs that drop prematurely and are chiefly filled with male flowers are preserved and introduced among the green growing figs with a view to their pollen being carried by insects to the flowers where they are wanted. To these processes the name of caprification has been given; but although sanctioned by a practice, the date of which is lost in antiquity, it has been conclusively proved by Professor Gasparrini that caprification produces no useful effect whatever upon the fig crop, and should be discontinued. (See 'Journal of the Horticultural Society,' vol. iii., in which the subject is very fully discussed.)

FIGURATE NUMBERS. [NUMBERS, APPELLATIONS OF.]

FIGURE (Geometry), a finite space, which has a boundary in every direction. The figure of a space is the notion we receive from observing its boundary.

FIGURE OF THE EARTH. [GEODESY.]

FIGURED BASE, in Music, is a line, or staff, written in the base clef, over the notes of which are placed figures representing certain chords. This is commonly called the *thorough-base.* [THOROUGH-BASE.]

The *figured base* is fallen into disuse, though we are of opinion that it might still be beneficially employed in scores. But in a piano-forte or organ part, when the harmony or accompaniment is given fully in the treble staff, figures are not only superfluous, but perplexing and incorrect.

FILBERT, the fruit of a variety of the hazel-nut, or *Corylus Avellana.* [CORYLUS.] The term was originally applied to those kinds of nuts which have very long husks, but owing to the number of varieties that have of late years been obtained, this distinction, which was never scientific, appears to be nearly disregarded, and nut and filbert are almost synonymous terms, excepting that the wild uncultivated fruit, and those varieties which most nearly approach it, are never called filberts.

The best sorts are the following:—

Frizzled filbert, excellent bearer.
Red filbert, } bad bearers.
White filbert, }
Cob-nut (Pearson's Prolific, 'Hort. Soc. Cat.'), a very prolific kind.
Bond-nut.
Cosford.
Large square Downton.
Northamptonshire, prolific.

According to the most skilful cultivators, the soil on which the filbert succeeds best should consist of "a hazel loam of some depth, upon a dry subsoil;" but as this is not always found convenient, it should be remarked that it is not essential to the growth of the filbert, and some even recommend a dry poorish soil. The ground should be frequently dressed (at least once in two years), and a small quantity of manure given; woollen-rags are often used for this purpose with the greatest success, but manure of any kind will be found beneficial.

Filberts are most successfully propagated by layers or suckers. The layering should be performed in the earlier part of the season, in order that the plants may be well rooted, and ready to plant either in a nursery, or where they are intended to remain, in the autumn. When they are raised from suckers, these are generally taken from the parent plant in the end of the season, and subjected to the same treatment as layers. If it be desirable that the trees should be dwarf, layering and grafting are recommended; but if strong plants are wanted, they are raised from suckers: it is also said they fruit sooner by the last method.

The method of pruning depends in a great measure upon the object the cultivator has in view: if dwarf trees are wanted, the layer or sucker is shortened to about one foot and a half or two feet; if what are termed riders be desirable, then the stem is cut much higher; but if the shoot is weak it is better to cut it near the ground, and leave it the proper height at the next year's pruning. Afterwards, when any sucker makes its appearance at the bottom of the stem, it should be carefully removed, and not allowed to draw the nourishment from the parent plant.

In the formation of the head, the chief thing to be observed is to form it regularly, cutting away all strong superfluous shoots, keeping it thin and open in the centre, and thus allowing the free passage of light and air. "There will be produced from the two and three years' branches, annually, short twigs of six or nine inches in length, which generally bear a great many nuts the following year; these should be thinned out, but not shortened, leaving them in tolerable quantity wherever they are produced, cutting them clean out the following winter, and leaving others in the same manner as those had been left the previous season." ('Lindley's Guide,' &c.)

About Maidstone, and other parts of Kent, the management of the filbert is better understood than in any other part of this country; and as the soil and other circumstances seem to suit its growth, immense quantities are grown for the London market. "That part of Kent where the filbert is chiefly cultivated is a loam upon a dry sandy rock. The Rev. W. Williamson advises every one to plant them where they are to remain, whether they are intended for a garden or a larger plantation; and after being suffered to grow without restraint for three or four years, to cut them down within a few inches of the ground. From the remaining part, if the trees are well rooted in the soil, five or six strong shoots will be produced. In the second year after cutting down, these shoots are shortened; generally one-third is taken off, and that they may appear regular, a small hoop is placed within the branches, to which the shoots are fastened at equal distances; by this practice, two considerable advantages are gained, the trees grow more regular, and the middle of each is kept hollow so as to admit the influence of the sun and air: but this in a large plantation would be almost impossible, nor indeed is it necessary, though in private gardens, where regularity and neatness are almost essential, it ought to be practised. In the third year a shoot will spring from each bud; these are suffered to grow till the following autumn, or fourth year, when they are cut off nearly close to the original stem, and the leading shoot of the last year shortened two-thirds. In the fifth year several small shoots will arise from the base of the side-branches which were cut off the preceding year; these are produced from small buds, and would not have been emitted, had not the branches on which they are situated been shortened, the whole nourishment being carried to the upper part of the branch.

"It is from these shoots that fruit is to be expected. These productive shoots will in a few years become very numerous, and many of them must be taken off, particularly the strongest, in order to encourage the production of the smaller ones; for those of the former year become so exhausted, that they generally decay; but whether decayed or not, they are always cut out by the pruner, and a fresh supply must therefore be provided to produce the fruit in the succeeding year. The leading shoot is every year shortened two-thirds, or more, should the tree be weak; and the whole height of the branches is not allowed to exceed six feet. Every shoot that is left to produce fruit should also be tipped, which prevents the tree being exhausted by making wood at the end of the branch. It frequently happens that a strong shoot springs from the root; and should any of the first year's or leading branches be decayed, or become unproductive of bearing wood, it will be advisable to cut that entirely away, and suffer the new shoot to supply its place, which afterwards is to be treated in the same way as is recommended for the others." ('Hort. Trans.' vol. iv.)

Such, according to Mr. Williamson, is the method of cultivating the filbert in the far-famed grounds of Kent, by which thirty hundred-weight per acre has been grown on particular lands; at the same time he acknowledges that failures are by no means unfrequent, but he attributes this to the excessive productiveness of successful years.

The filbert is a monœcious plant, having its male organs in one flower and its female in another; and one modern writer, suspecting a want of male blossoms to be the cause of failure in particular seasons, suspended a quantity of the catkins of the common hazel over the female blossoms of some of his filberts, the result of which was a greater quantity of fruit than his trees had borne for many years. He then tried some *with*, and others *without*, the male flowers, when the former bore fruit, and the latter proved abortive, as he had anticipated. He therefore recommends unpruned hazels to be planted among the cultivated filberts, in order that impregnation may be effected.

Great quantities of filberts are rendered useless by being attacked by the *nut-weevil* (*Balaninus nucum*), which perforates the nut in its young state, and deposits its egg: in a few days the maggot is hatched, and then feeds upon the kernel. Some recommend the trees to be shaken in June or July, as this is the time when the insect makes its appearance, but no remedy is known which can be said to be effectual.

In order to preserve filberts in a fresh and plump state, it is only necessary to prevent their parting with their moisture by evaporation. Burying them in heaps in the earth, putting them in earthen jars in a wine-cellar with a small quantity of salt dusted over them, covering them with dry sand, are all good plans, and many others equally efficient will suggest themselves.

FILE MANUFACTURE. Files are steel tools having flat or curved surfaces so notched or serrated as to produce a series of fine teeth or cutting edges. They are indispensable for the working of most metallic and many other hard substances; and without their aid few articles of machinery could be produced. The use of the file must have preceded every step in the progress of finishing articles composed of iron and steel, in all cases where any intricacy of shape precluded the operation of grinding. In the first book of Samuel (chap. xiii. v. 21), the file is mentioned as the means of sharpening the mattocks, coulters, and other edged instruments of the Israelites; and it may be mentioned as a further proof of the antiquity of this tool, that in Homer's 'Odyssey,' Vulcan is represented as using the hammer and file in fabricating the net in which he entangled Mars and Venus.

Files always are, or should be, made of steel of superior quality; as there are few instruments in which a defect in the metal is so completely destructive of utility. An axe, saw, or almost any other cutting instrument, though of inferior metal, may be made to do its duty by repeated whetting; but for a bad file there is no remedy,—no process of restoration. If too soft, the teeth wear down quickly; if too hard, they chip off. Steel for making files, being required to be of unusual hardness, is more highly converted than for other purposes, and is sometimes said to be *double converted.* The very large files called smiths' rubbers are generally forged immediately from the converted bars, which are, for convenience, made square while in the state of iron. Smaller files are forged from bars or rods which are wrought as nearly as may be to the required form and size by the action of tilt-hammers, either from blistered bars or from ingots of cast steel. These bars are cut into pieces suitable for making one file each, which are heated in a forge fire, and then wrought to the required shape on an anvil by two men : one of whom superintends the work, and is responsible for the goodness of the file, while the other acts as general assistant. Files being of many different shapes and sizes, as square, triangular, flat, round, and half-round in their cross section, and parallel or tapering more or less towards the end, and ranging from the minute watchmaker's files of an inch or two in length, to the ponderous rubber of two or three feet, there are of course many varieties in the forging process. The square and flat files are generally shaped by the hammer only ; but for those of a triangular or half-round section grooved bosses or dies of the required shape are attached to the anvil. Round files are made by means of the instrument known to smiths as a *swage*, which may be compared to a pair of such dies, one of which is inverted upon the other to receive the blows of the hammer. The projecting tang by which the file is to be inserted in a wooden handle is formed at this time, and the manufacturer's mark is impressed with a steel punch.

The next operation is that of softening or annealing, to render the steel capable of being cut with the toothing instruments. The ordinary mode of performing this operation is to pile the steel blanks loosely upon the bottom of a brick oven, and heat them with a fire kindled beneath and around them, the heat being regulated by dampers. When the fire has been maintained sufficiently long, the pile is smothered with ashes, every aperture by which air could enter the oven is carefully closed, and the whole is left to cool gradually. The access of air during the heating tends to the oxidation of the steel, and is consequently injurious : and on this account a more careful method of annealing is sometimes adopted, by means of a closely-covered box filled with sand, into the midst of which the blanks are plunged.

After annealing, the surface of the metal must be rendered very smooth and even before cutting the teeth. This may be done either by *stripping*, or filing, first across, and afterwards along the surface ; or by grinding upon very large grindstones. The stripping process, which is tedious and laborious, was formerly in common use, and is still practised by some filemakers, especially in Lancashire, where excellent files are manufactured ; but the other is now the most common method.

The cutting of the teeth is usually performed by workmen sitting astride upon a board or saddle-shaped seat, in front of a well-lighted bench, upon which is fixed a kind of small anvil. Laying the blank file across the anvil, the cutter secures it from moving by a strap which passes over each end and under his feet, like the stirrup of the shoemaker. He then takes in his left hand a very carefully ground chisel made of the best steel, and in his right a peculiarly shaped hammer, the handle of which is fixed at such an angle that the operator can, while making a blow, pull the hammer rather towards him. If the file be flat, or have one or more flat surfaces, the operator places the steel chisel upon it at a particular angle, and with one blow of the hammer cuts an indentation or furrow, completely across its face from side to side, but most commonly in an oblique direction ; the metal displaced by this operation is not taken away, but is thrown up in the form of a prominent angular ridge, with a sharp cutting edge, on one side of the furrow. He then moves the chisel a little, and by a second stroke cuts another precisely similar furrow parallel to, and at a very short distance from, the first ; and thus proceeds, stroke by stroke, until the whole surface is furrowed, beginning at the point and ending at the tang-end. In the course of cutting, the file is gradually moved from the operator by relaxing the pressure of the strap from time to time. In this state, the file is said to be *single-cut*, or *single-float ;* and files so cut are used for brass and the softer metals, which are liable to clog a file of any other kind. For working iron and some other materials, *double-cut*, or *cross-cut*, files are used ; in which the first row or series of cuts is crossed at an oblique angle by a second ; the effect of which is to convert the surface into a collection of very small angular teeth, admirably adapted for the abrasion of hard substances. In making cross-cut files, a fine file is gently passed over the first series of cuts or teeth to reduce the prominences to an even surface before the second set is cut. Files for wood are usually cut with a triangular pointed punch or chisel, instead of one with a flat edge ; such files, as well as some of the deepest and coarsest cross-cuts, are called *rasps*. If the file be round or half-round, or have any curved surface, it is still cut with the same kind of tool ; but as a straight-edged cutting tool can only make a short indentation upon a convex surface, it is necessary to go round the file by degrees, making several rows or ranges of minute cuts contiguous to one another.

In addition to variations in the form and arrangement of the teeth of files, their size varies extremely. The largest and coarsest smiths' files are called rubbers ; and others, arranged in order of fineness, are technically known as rough, bastard, second-cut, smooth, and dead-smooth files, the latter producing so fine a surface when applied to metal that the subsequent application of a burnisher is sufficient to polish it.

In the art of file-cutting there are many points worthy of remark. The angle at which the cuts are made depends greatly on the purpose to which the file is to be applied, and is made an especial object of the cutter's attention. The cut, too, is not a mere indentation, made without reference to form ; it is a triangular groove of particular shape, the production of which requires a most discriminating tact in the management both of the hammer and of the cutting-tool. Then, again, the strict parallelism of the several cuts can only be brought about by practised accuracy of hand and eye ; since there is no guide, gauge, or other contrivance for regulating the distance. In a round file, too, the several rows or cuts are brought side by side in such an exact manner that it is difficult to conceive them to be formed singly and by hand. It is possible, in a half-round file 10 inches long, to make 20,000 chisel-cuts, each produced by a distinct blow from a hammer ; and files of that length are actually made *single-cut*, with 10,000 such indentations.

The final process in the manufacture of files is the hardening of the steel, a process in which different manufacturers vary in practice. There are differences, too, depending on the degree of hardness required. In the ordinary process of hardening steel files three things must be particularly observed : first, to cover the surface of the file with some composition which, acting as a protecting varnish to it, may guard it from oxidation and scaling when exposed to the action of the fire, that the sharpness of the teeth may not be impaired, nor the surface rendered rough, which would cause it to clog when in use ; secondly, to heat it very uniformly throughout to a red heat ; and, thirdly, to cool it suddenly, by immersion in the freshest and coldest water, in such a manner as to impart the greatest degree of hardness, and to avoid the tendency to warping, which in long thin files is a difficult matter. A mixture very commonly used for the first-mentioned purpose consists of the grounds of malt liquor, or the cheapest kind of flour, yeast, and common salt. The use of the grounds is chiefly to enable the files to retain a greater quantity of salt, which fuses, and forms a protecting varnish when in the fire. The heating is usually effected in an open fire of clean coke, the file, if small, being held by the tang end in a pair of tongs, and frequently withdrawn, to see that no part becomes over-heated. The proper temperature is indicated by a cherry-red colour. A kind of oven is sometimes used for large files, to facilitate the uniform application of heat, the oven being formed of fire-bricks, open at one end to receive the files and fuel, and the fire being urged by bellows. Some file-makers put sulphuric acid or other substances into the quenching-water, with a view to procuring the greatest possible hardness. All files should be immersed quickly ; those of a flat, square, triangular, or round form, being plunged perpendicularly into the water ; while the half-round, though kept perpendicular, should be moved a little horizontally in the direction of the round side, to prevent its becoming crooked. With every precaution the files are liable to take some degree of warp or curvature in this process, to remove which they are withdrawn from the water before they become quite cold and straightened. Owing to their hardness, files are unavoidably brittle, and they are especially liable to break by the tang, owing to their reduced substance ; to remedy which, some makers temper the tang end by dipping it in a bath of melted lead. During the war of the French revolution, the supply of English files being impeded, the French file-makers were excited to great efforts to supply the deficiency ; and these efforts are said to have resulted in the production of files of intense hardness, by dipping them into a composition of mutton suet, hog's lard, and arsenic.

After hardening, the files are scoured with a brush dipped in water mixed with a little sand or coke-dust ; then thoroughly washed to remove any saline particles which might tend to rust the file ; next dipped in water in which quick-lime has been dissolved, in order to neutralise the effect of any which may yet remain ; and finally dried before the fire, brushed over with oil or a mixture of olive-oil and turpentine, and wrapped up in oiled brown paper for sale. Before packing, files are sometimes tested by striking them gently on a piece of hard steel, and also rubbing them gently from end to end.

When files, otherwise of good quality, are reduced to a useless state by wear, they are sometimes re-cut, the old teeth being completely removed by grinding. Re-cut files are, of course, somewhat thinner than when first made, but in all other respects they may be equally good, if the process is properly conducted. Owing to the superior quality of the steel, worn-out files bear a comparatively high value as old metal, and many are bought up for the purpose of converting them into screw-drivers and gun-barrels.

Several highly ingenious machines have been contrived for superseding the tedious operation of file-cutting by hand ; but, suited as the process may appear to be for the use of machinery, it has been found to present such great difficulties that few file-cutting engines have been brought successfully or extensively into operation. One very serious difficulty arises from the circumstance that if one part of the file be either a little softer than the adjacent parts, or narrower, so as to present less resistance to the blow of the hammer, a machine would, owing to the perfect uniformity of its stroke, make a deeper cut there than elsewhere ; whereas a workman who has been employed in the trade from a boy can feel instantly when he arrives at any variation in the quality or condition of the steel, and at once adapts the weight of his blow to it. The application of machinery to the toothing of extremely fine-faced files seems conceivable however, because in such the *set* or direction of the teeth is a matter of much less importance than perfect equality of surface. The double dead-cut files of the

French exhibit such a beautiful uniformity of delineation when examined with a magnifier, that no doubt seems to be entertained by many persons conversant with the art of their being cut by machinery of some sort. But although the French are so successful in the production of this exquisitely delicate cutting, they are not equally so in the execution of the rougher sorts; and, consequently, English files are in high reputation in Paris, whither large quantities are regularly transmitted. As an example of minute but useless work, we may adduce the Danish file sent to the Great Exhibition in 1851. It was four-square, and weighed 10 lbs.; the file-cuts on the surface represented the royal arms, and views of several public buildings in Copenhagen. It was hollow, and contained a nest of ten files, one within another, the innermost being little more than an inch in length. Still more pretentious was a file made by Hiram Younge, a file-cutter in the employ of Messrs. Carr of Sheffield; it was 54 inches in length, and was covered all over with landscapes, emblems, symbols, inscriptions, foliage, and other devices, all produced by chisel-cuts of different lengths and depths.

A brief notice of three among the many machines invented within the last few years will illustrate the modes in which the cutting-action is brought about, and will also show that there are really machine-cut files now made in England. In 1856, a file-cutting machine, invented by Mr. Ross, was adopted in Messrs. Hetherington's works at Glasgow; and by the spring of the next year, five others had been added. The chief difficulty hitherto has been in the attainment of a proper modification of blow, so as to suit various qualities of steel, widths of file, and depths of cutting; and also to accommodate the blow to any irregularities of surface. These difficulties Mr. Ross has sought to remove, by an ingenious but very complex arrangement of mechanism —calculated to produce files of a medium degree of size and fineness. In Messrs. Preston and Macgregor's machine, patented in 1858, there is a shaft turned by a strap in the usual way; conical cams, fixed on the shaft, raise and lower a hammer-head and spindle; there are fixed guides on the anvil block; the upper swage is fixed at the lower end of the spindle, and the lower swage between the guides; and thus the blows of the hammer are brought down vertically. The lift of the hammer is varied by varying the distance between the cams on the shaft. There is a chisel-holder with a ball-joint, and a spring for retaining the holder in its place. There is a compensating movement for regulating the force of the blow. The file-blank is placed in a recess in the anvil. Messrs. Greenwood and Batley set up at Leeds, in 1859, a file-cutting machine of French invention. The file, in this arrangement, is placed in a self-adjusting bed, capable of turning in any direction; the chisel is fixed in a vertical slide, put in motion by a spring and cam and gives about a thousand blows in a minute. It is said to do about as much work as ten skilful file-cutters. This form of machine is also in operation in France and Belgium.

Files are among the articles which exemplify the importance of trade-marks. A mark was granted many years ago by the Sheffield corporation to Daniel Brammall, to be stamped on his files; and so important was this in a commercial point of view, that on one occasion Brammall obtained 2000*l*. damages against a rival manufacturer, for an infringement of the mark. This matter was adverted to by one of the jurors of the Paris Exhibition in 1855, in connection with the file-manufacture:—"The fundamental obstacle to the growth of this branch of industry results from the custom adopted by almost all manufacturers of placing false marks on their produce. This deplorable custom is due in part to the desire that unconscientious manufacturers, convinced of their real inferiority, have to turn to their own profit the resources of the best foreign manufacturers, acquired by a long career of honesty and talent; it is encouraged by the retail dealers, who wish to keep manufacturers dependent on them, and to hinder the consumer from knowing the real marks of steel goods. Manufacturers, short of capital, submit in this matter to the terms dictated to them by the dealers, renounce their individuality, and stamp upon their goods such marks as the buyer chooses to order, and even to substitute the name of the retail dealer for their own. The history of the English steel trade proves that a skilful manufacturer, who consecrates his life to found the reputation of the trade-mark he has chosen, can leave in the sole possession of that mark a large fortune to his descendants. The government would, therefore, render skilful and conscientious manufacturers (the only ones that ought to be encouraged) an immense service in imposing upon each producer the obligation to place his own mark upon his manufactures." It is probable that this mention of government interference was due to a Frenchman, with whom such a mode of settling trade difficulties is familiar. In reference to the file-manufacture, the chief piracies occur in Germany, where English trade-marks are copied with unblushing effrontery.

FILE, is a line of soldiers one behind the other. The term is commonly used also to designate a front and rear rank man together; or as in the expression so many rank and file, when it means so many soldiers who are not officers or sergeants.

FILE MARCHING, is where a line of soldiers, either in single or double rank, facing to the right or left, march in that direction; each front and rear rank man then compose a file.

FILIATION, ORDER OF. [BASTARDY.]

FILLET, a flat rectangular moulding, of very frequent occurrence in architecture. It is used to terminate or divide other mouldings, as in the cavetto, which is surmounted with a fillet, and in the flutings of columns, which are divided by a fillet. The fillet is much used in entablatures. [COLUMN.]

FILTER; FILTRATION. Filters may be ranked as of four kinds: those employed in straining various chemical liquids; those used for filtering water in small quantities for household use; those used on a large scale by the water companies; and those used on shipboard for converting salt water into fresh.

1. *Chemical filters.* The smaller kinds are strainers used in chemical operations for rendering fluids transparent by separating the suspended impurities which make them turbid; or for separating and washing the precipitates resulting from chemical analysis. They are usually made of unsized or blotting paper; and they are used either spread out upon cloth stretched on a wooden frame, or folded and placed in funnels, and having consequently the form of an inverted cone. They are either single or double, according to the purposes to which they are to be applied. [CHEMICAL ANALYSIS.]

2. *Household filters.* Various forms of filter are employed for the purpose of filtering water, either for drinking or culinary purposes. These filters generally depend upon passing water through sand or small pebbles and charcoal. It is well known that the Thames water, though it contains but little saline matter in solution, is frequently turbid, owing to mechanical admixture of earthy matter; and these earthy matters, in the Thames and other kinds of river water, it is the purpose of filters to remove, so as to render the water, though not so agreeable as spring-water for drinking on account of its flatness, yet well adapted for other purposes.

A considerable portion of the river-water of Paris is filtered in large establishments where it is employed. The filters made use of are small boxes, many in number, lined with lead, open at top, and having at the bottom a layer of charcoal between two layers of sand. If the water is foul, the upper layer of sand requires to be renewed daily. At the Hôtel Dieu the boxes are hermetically sealed, and the water is forced through the filtering layers by artificial pressure.

A very simple water-filter may be made of a common garden-pot, or similar vessel, with a bottom pierced with holes. Fill the lower part with round pebbles, then place a layer of smaller pebbles, then coarse sand, and lastly a layer, three or four inches in depth, of well-made pounded charcoal. The water, in percolating through these various strata, loses nearly all its mechanical impurities. A still simpler filter may be formed of a layer of sponge pressed between two perforated plates.

Murray's Self-cleansing Domestic Tubular Filter is soldered to the end of the service-pipe. The enlarged part of the pipe contains a perforated tube with several folds of flannel and linen wrapped round it. The smaller tap communicates only with the outer casing, so that no water can reach it that has not passed through the filtering tube. The larger tap communicates with the interior of the tube; and by allowing it to run, the filter will cleanse itself. In Bird's Hydrostatic Syphon Water Purifier, the filtration is performed in two inverted cones containing filtering media, situated in the cylinder. When used, the instrument is immersed in the water to be filtered, and the pipe uncoiled so as to hang with its stop-cock below the bottom of the instrument. On drawing out the air from the pipe, it acts as a syphon, and a stream of pure water flows. Foster's Pressure Filter, recommended for use by the Sanitary Board of Liverpool, consists of a porous stone, hollow in the inside, and contained in a metal jacket. This apparatus, when screwed into the service-pipe, causes the water, forced through the stone by the pressure of the main, to lose all its pollutions, and come out pure and clear. There are two taps, one of which draws the filtered water from the interior of the stone globe; the other the unfiltered from the exterior; and the apparatus is so arranged that the drawing of the unfiltered water cleanses the stone and increases its powers of filtration.

Some of the filters recently made have for their object the maintenance of a uniform pressure of the fluid upon the filtering surface by a self-acting contrivance, which admits the fluid from a reservoir just as fast as it passes off through the filter. On a small scale this may be done by inverting a bottle, filled with the liquid to be filtered, with its open neck or mouth in the funnel or other vessel at the bottom of which the filtering materials are placed; so long as the fluid in the funnel is above the level of the mouth of the bottle, no fluid will flow from the bottle into the funnel, because no air can enter the bottle to take its place; but so soon as, by the process of filtration, the fluid in the funnel falls below the mouth of the bottle, air enters it, and consequently liquid flows out into the funnel until it rises high enough again to prevent the admission of air. In other cases, the admission of fluid to the filter is regulated by a ball-cock or valve connected with a float. In a few instances, hydrostatic or pneumatic pressure is employed to increase the rapidity of filtration, by closing the filtering cylinder, and forcing the fluid into it, either by a force-pump or by a pipe from an elevated cistern; by producing pressure by air or steam upon the surface of the fluid; or by occasioning a partial vacuum beneath the filter, in the vessel which receives the fluid after it has passed through it. When such pressure is applied, the water or other fluid is sometimes caused to *ascend* through the filtering materials, or to pass through them horizontally, or in any required direction. In some filters, the action is compounded of descent by gravity and ascent by hydrostatic pressure; by which arrangement the fluid may be compelled to pass through a great quantity of filtering material in a small space. In one form, the filtration is carried on without any exposure to the access of air; both the vessel into which the impure fluid is put, and that which receives it after filtration, being hermetically closed. These two vessels are connected together by a small air-pipe, through which the air displaced from the lower vessel by the dropping of the fluid into it ascends into the upper vessel to occupy the space which it has just vacated. The process therefore is conducted without the contact of any more air than the vessels contain at its commencement, and without the escape of any vapours from the fluid; so that the most volatile liquids may be filtered without loss, and the injurious effects which in other cases might arise from the free admission of air are avoided.

In Ransome's filter, patented in 1856, there is a cylindrical vessel, at the bottom of which is a layer of coarse grit; above the grit is a layer of fine sand; and above this a slab of Ransome's patent porous stone. In the middle of the porous slab is a hollow space containing a layer of charcoal. Above all these layers is a vessel for filtered water; and above and around this another for unfiltered. The impure water runs down to the bottom of the vessel, and then ascends through all the layers, leaving the impurities behind it. Filters of this kind are found to be more easily cleaned than those which act by descension. Ransome's patent stone has led to the production of a very small and simple filter, intended for troops, travellers, and emigrants. It consists of a small cylinder of porous stone, attached to a disc of wood; from which disc springs a short vulcanised india-rubber tube, with a mouth-piece. On placing the cylinder in unfiltered water, and drawing breath through the tube, water rises in a tolerable state of purity, and flows into the mouth.

3. *Filtering Beds.*—The processes for filtering water on a large scale, as now adopted by the chief water-works companies, will best be treated in the article WATER-WORKS.

4. *Freshening Sea-Water.*—This important process, becoming every year more appreciated and more extensively adopted, belongs rather to distillation than to filtering; but it was referred from DISTILLERY to this place, because many of the forms of apparatus employed comprise filtering as well as distilling arrangements. It may not at first sight appear evident how the saltness of sea-water can be removed by either of these processes. The explanation is found in the fact, that whenever water is converted into steam at an ordinary temperature, very few if any solid particles ascend with it. Salt, clay, sand, charcoal, alkalies, and oxides, are almost wholly left behind in the vessel in which the water is treated; the vapour which passes off consisting of aqueous particles and a little atmospheric air. If clear water, dirty water, or sea-water be placed in a common kettle on the fire, the steam that issues from the spout will be nearly alike in all three cases; it will be vapid and tasteless, but neither salt nor impure. The possibility of rendering sea-water drinkable is a question of very great importance to ship-owners, especially to the owners of emigrant and passenger ships, and to the royal navy; for, under present arrangements, a vast space and a vast number of tanks are necessary to contain fresh water enough for the wants of all the crew and passengers; and even if fresh when put on board, the water has a tendency to become foul by long keeping. The miseries suffered on ship-board by a deficiency of pure water are among the greatest to which passengers and crew are liable.

All the many forms of apparatus invented for freshening sea-water are contrived with a view to making the best use of the fuel employed; those which are most economical are most likely in the end to be adopted. Grant's apparatus, brought forward in 1849, is so contrived that the same fire employed for the cooking of the crew's provisions will distil sea-water contained in a vessel above it, at the rate of one gallon per man per day. The water becomes aerated, or mixed with sufficient atmospheric air to impart briskness to it, by agitation in the vessel. McBride's apparatus, patented in the same year, condenses the heated sea-water by a current of cold air, which gathers it into a condenser by means of a blowing or exhausting machine. Murdoch's apparatus comprises a pipe fitted in the top of the ship's cooking boiler, and another perforated pipe to admit air; an exhausting space sucks both the steam and the air down the pipe into a condenser beneath, thereby effecting simultaneously the distilling and the aerating. In Ericsson's apparatus, when the sea-water has been converted into vapour, the steam passes into and through a space between two concentric vessels; the inner vessel is kept cool by the flow of cold water through it, and the outer one by the evaporative action of the atmosphere on a wet cloth wrapper; and the steam being thus placed between two cool surfaces, becomes condensed into drinkable water. In Normandy and Fell's apparatus, the arrangement is somewhat peculiar. There is a cylinder surrounded by a steam-jacket. The cylinder is divided internally into four channels or compartments by partitions. Each of these compartments is turned up at one end, so as to allow the water to flow towards the other. The cylinder is connected at one end to a pipe with a condensing and aerating apparatus, contained within a closed tank; and at the other by a pipe with a box, into which the water to be purified is first introduced. A pipe brings steam from a boiler into the jacket, to heat the cylinder. The sea-water within the cylinder is made to flow through all the compartments, by means of the partitions; it gets heated as it goes, and throws off steam. This steam passes off through the pipe into the condenser, where it gets mixed with atmospheric air, and is finally condensed by coming in contact with the sides of the condenser. The steam which has been employed in heating the cylinder when condensed by cold, is drawn off by another pipe; although it is not pleasant to drink, through not being aerated, it is still good enough for washing. The residuum of the salt or impure water escapes by another pipe. Gravely's apparatus, patented in 1858, consists of two parts, a boiler and a condenser, the latter over the former. The bottom of the boiler is corrugated, to increase the heating surface, and there is a jacket to economise the heat. A pipe extends from an aperture in the top of the boiler to near the top of the condenser; a larger pipe is outside and concentric with this; and the space between them is an air-space.

Messrs. Gravely have recently paid much attention to their apparatus, to render available as much as possible of the heat which in ordinary ships is usually generated in the cook-room; and their success has been such as to lead to a large employment of the apparatus in merchant ships. Grant's apparatus, applied some years ago to H. M. S. Arrogant, Plumper, Reynard, Dauntless, Termagant, and Encounter, has recently, modified and improved by other contrivances, been provided for a large number of ships in the royal navy. When Sir Charles Napier was in the Baltic with his fleet, eleven ships distilled 4,700 tons of sea-water; and did this so well, that the crew preferred the water thus obtained to ordinary fresh water. In the Black Sea during the same war, the ship Wye distilled 10,000 gallons a day. Very recently (1859) Dr. Normandy, improving on an apparatus in which he was concerned some years earlier, has brought it to a more efficient state than any other for the Royal Navy; it is now being largely adopted by the Admiralty, and by the great steam mail companies.

FILTRATION. A process used in chemical operations to separate solid from liquid matter. [CHEMICAL ANALYSIS.]

FINA'LE (Ital. *Fi-ná-le*), the concerted piece of music by which the acts of an opera conclude: the last movement of a symphony, concerto, &c.

FINANCE. [TAX; TAXATION.]

FINE OF LANDS, one of the modes of conveying lands and hereditaments by matter of record. It was so called because it put an end not only to the actual suit of which it was the conclusion, but also to all other suits and controversies concerning the same matter. Divested of its technicalties, a fine may be described to be an amicable composition or agreement of a suit, either actual or fictitious, by leave of the king or his justices, whereby the lands in question become, or are acknowledged to be, the right of one of the parties.

The note of the fine was read four times openly in the Court of Common Pleas, or as it was called, proclaimed, once in the term in which it was made, and once in each of the three succeeding terms, during which all pleas ceased, and these proclamations were endorsed upon the record. A table of the fines levied in each county in every term was affixed in some open part of the Court of Common Pleas all the next term, and a copy of the same was given to the sheriff of every county, who at the next assizes fixed the same in some open place in the court, for the more public notoriety of the fine. (Bl. 'Com.' vol. ii. p. 351, Mr. Kerr's ed.)

Of the effect of a Fine.—A fine was a conveyance so effective that it bound not only those who were parties and privies to the fine, but all other persons whatsoever, unless they brought their action or made lawful entry within five years after proclamation made, except married women, infants, prisoners, persons beyond the seas, and such as were not of whole mind, who had five years allowed to them and their heirs after the death of their husbands, their attaining full age, recovering their liberty, returning into England, or being restored to their right mind. Persons also who had not a present, but a future interest only, as those in reversion or remainder, had five years allowed them to claim in from the time their right accrued by the stat. 4 Henry VII. c. 24.

In order to make a fine of any avail at all, it was necessary that the parties should have some interest or estate of freehold in the lands to be affected by it. (Bl. 'Com.' vol. ii. p. 358, Mr. Kerr's ed.) But it was not necessary that the freehold should be in either of the parties by right, and therefore when a fine was levied to strengthen a title, it was frequently considered necessary to make a feoffment, in order that the freehold might be in one of them by disseisin. [FEOFFMENT.] If neither of the parties had any interest at the time, although the fine had no proper operation, yet it might take effect as between them by way of estoppel. [ESTOPPEL.]

A fine was principally used as the mode of conveying the estates of married women, and renouncing their right to dower, as a means of barring estates tail, and remainders and reversions dependent upon other estates, and also for the purpose of strengthening defective titles.

By the 3 & 4 Will. IV. c. 74, fines are abolished, and provision is made for the conveyance of the interest of married women in land, with the concurrence of their husbands, and after being examined to ascertain if they are acting voluntarily, by a deed to be acknowledged in the Court of Common Pleas; and provision is also made for the barring of estates tail by a deed enrolled: but no provision is made for enabling parties whose titles are defective to strengthen them by any means analogous to a fine and nonclaim. (2 Bl. 'Com.'; Cruise, 'On Fines.'

This mode of conveyance, which was in use from the earliest periods of English history of which we possess any authentic judicial records, has been recently abolished by the stat. 3 & 4 Wm. IV. c. 74; yet the rules by which it was governed form a very considerable branch of real property law, and it is therefore desirable briefly to describe its nature and effect. Fines were of four kinds:—1. A fine "sur conusance de droit, come ceo qu'il ad de son done;" that is, upon acknowledgment of the right of the cognizee, as that which he (one of the parties to the fine) had of the gift of the cognizor (the other party to the fine). This was the best and surest kind of fine, for thereby the cognizor (the person in possession, also called the deforciant from keeping the cognizee out of possession), in order to make good his covenant with the cognizee (the plaintiff), of conveying to him the lands in question, and at the same time to avoid the formality of an actual feoffment and livery, acknowledged in court a former feoffment, or gift in possession, to have been made by him to the plaintiff. This fine is therefore said to have been a feoffment of record, the livery thus acknowledged in court being equivalent to an actual livery; so that this conveyance was rather a confession of a former conveyance than a conveyance then originally made. 2. A fine "sur conusance de droit tantum," or upon the acknowledgment of the right merely; and not with the circumstance of a preceding gift from the cognizor. This was commonly used to pass a reversionary interest; for of such there could be no feoffment with livery supposed, as the possession during the preceding, or, as it is technically called, particular estate, belonged to a third person. [FEOFFMENT.] This kind of fine was worded in this manner: "that the cognizor acknowledges the right to be in the cognizee, and grants for himself and his heirs that the reversion after the particular estate determines shall go to the cognizee." 3. A fine "sur concessit," which was where the cognizor, in order to make an end of disputes, though he acknowledged no precedent right, yet granted to the cognizee an estate usually for life, or for years, by way of supposed composition. And this might be done reserving a rent or the like, for it operated as a new grant. 4. A fine "sur done, grant, et render," which was a double fine, comprehended the fine "sur conusance de droit come ceo," &c., and the fine "sur concessit." This might be used to create particular limitations of estate, whereas the fine "sur conusance de droit come ceo," &c., conveyed nothing but an absolute estate of inheritance, or at least of freehold. In this last species of fine, the cognizee, after the right was acknowledged to be in him, granted back again, or rendered to the cognizor, or perhaps to a stranger, some other estate in the premises. But in general, the first species of fine, "sur conusance de droit come ceo," &c., was the most used, as it conveyed a clear and absolute freehold, and gave the cognizee a seisin in law, without any actual livery, and it was therefore called a fine executed, whereas the others were but executory.

Fines of all four kinds were thus levied, to use the technical term: First, the party to whom the land was to be conveyed commenced an action or suit at law against the party who was to convey, by suing out a writ or *præcipe*, called a writ of covenant. The action was founded upon the breach of a supposed agreement or covenant, that the one should convey the lands to the other. On this writ a fine, called a *primer fine*, amounting to about one-tenth of the annual value of the land, became due to the king. The suit being thus commenced, then followed,—Secondly, the "licentia concordandi," or leave to compromise the suit, upon which also another fine, called the king's silver, or sometimes the post fine, became due to the king, amounting to about three-twentieths of the annual value of the land. Thirdly, came the concord or agreement itself, which was required to be made either openly in the Court of Common Pleas or before the lord-chief-justice, or one of the judges of that court, or two or more commissioners in the county specially authorised; all of whom were bound by stat. 18 Ed. I. s. 4, to take care that the cognizors were of full age, sound memory, and out of prison. If a married woman was a cognizor she was privately examined by the parties before whom her acknowledgment was taken, whether she did it freely and willingly, or by compulsion of her husband. A fine was the only way in which a married woman could convey her freehold interest in lands.

By these several acts the essential parts of the fine were completed, and even if the cognizor died, still the fine might be carried on in all its remaining parts, of which the next was—Fourthly, the note of the fine, which was simply an abstract of the writ of covenant and the concord; naming the parties, the parcels of land, and the agreement, for the purpose of enrolment of record in the proper office. The Fifth and last part was the foot of the fine, which included the whole matter, reciting the parties, day, year, and place, and before whom it was acknowledged or levied. Of this indentures were made or engrossed at the chirographer's office, and delivered to the cognizor and the cognizee, usually beginning thus: "hæc est finalis concordia" ("this is the final agreement"), and then reciting the whole proceeding at length.

FINGER-BOARD, the whole range of keys, white and black, of a piano-forte or of an organ.

FINGERING, in music, is the art of so applying the fingers to a musical instrument, the piano-forte and organ especially, as to accomplish the objects in view in the easiest and most effective manner. A proper notice of the art of fingering, accompanied by the necessary examples, would require many pages; we shall therefore only remark in this place that, as a system, Clementi's is the best that we are acquainted with; though some few modern improvements have been made in its details.

FINIAL, a term used to designate the knob of foliage, or the floral ornament which crowns the apex of pinnacles, pediments, canopies, low spires, and occasionally gables, pointed dripstones, &c. in Gothic buildings. Formerly, pinnacles were frequently called finials, but the term is now limited to the top ornament. [GOTHIC ARCHITECTURE.]

FININGS. In brewing, and other manufacturing operations, a process of clarifying or clearing is required, for which some substance is employed under the name of *fining*. Some of these finings are made by the persons who are to use them; while others are purchased from the makers. Isinglass is made into finings by mixing it with beer or cyder, stirring until the isinglass is dissolved, straining through a sieve, and finally bringing it to a liquid state by mixing with the same kind of beverage as that which is to be fined. This is a fining much used by brewers. Distillers or rectifiers, in clarifying gin and cordials, use a fining composed of alum mixed either with carbonate of soda or salt of tartar and hot water.

It is a disputed point whether finings are really necessary in well-brewed malt liquors in good condition. Mr. Cooley and Dr. Ure decide this in the negative. The former observes: "Good liquors, either fermented or spirituous, need no artificial fining, as they always clarify themselves by repose. With those, however, which are out of condition, or of inferior quality, it is often necessary; as without such a proceeding they remain unsaleable. This is particularly the case with malt liquors." "Attempts to clarify it in the cask," says Ure, "seldom fail to do harm. The only thing that can be used with advantage for fining foul or muddy beer is isinglass. The disadvantages resulting from the artificial clarification of fermented liquors are, that the liquors do not afterwards stand well on draught; that much of the conservative astringent matter which they contain is precipitated with the finings; that their piquancy and flavour are more or less diminished; and that they are more than usually liable to become flat and vapid, whether in cask or in bottle. The larger the proportion of finings used, the more marked are their injurious effects, and the shorter the interval which elapses before the accession of the several symptoms referred to. We have seen the most disastrous consequences follow the injudicious use of finings, more especially in respect to those liquors in which a certain amount of piquancy, astringency, and briskness is an essential condition. In one instance which came under our notice, upwards of thirty barrels of 'underground,' a very strong old ale, was thus reduced in value to less than one-third of its original cost; and in another, a large bottled stock of the finest old Burton was found to be utterly unsaleable. In both cases, the spoiled liquor was got rid of by mixing it in, and selling it with, 3*d*. and 4*d*. ale."

FINITE (in Mathematics), having a boundary, used as opposed to INFINITE.

FIR, ECONOMICAL USES. In giving a brief notice of some of the remarkable and numerous uses of the fir-tree, we shall include at the same time the pine, which is so nearly allied to it as to have been placed by some botanists in the same genus.

The timber of the fir and pine is, perhaps, all things considered, more generally useful than that of any other tree. It is far excelled in strength and toughness by the timber of the oak, elm, beech, &c.; but it is more easily worked, and is durable enough for a large number of purposes. Some kinds are useful for the masts of ships; others for parts of the hull; others for flooring-boards. What Michaux says of the use of the white pine in North America will serve as well as anything else to denote the wide range of usefulness possessed by this timber: "The ornamental work of the outer door, the cornices of apartments, and the mouldings of fire-places, all of which in America are elegantly wrought, are of this wood. It receives gilding well, and is therefore selected for looking-glasses and picture-frames. Carvers employ it exclusively for the images that adorn the bows of vessels, for which they prefer the kind called the pumpkin pine. At Boston, and in other towns of the Northern States, the inside of mahogany furniture and of trunks, the bottoms of Windsor-chairs of an inferior quality, water-pails, a great part of the boxes used for packing goods, the shelves for shops, and an endless variety of other objects, are made of white pine. In the district of Maine it is employed for barrels to contain salted fish, especially the kind called the sapling pine, which is of a stronger consistence. For the magnificent wooden bridges over the Schuylkill at Philadelphia, and the Delaware at Trenton, and for those which unite Cambridge and Charlestown with Boston, of which the first is 1500, and the second is 3000 feet in length, the white pine has been chosen for its durability. It serves exclusively for the masts of the numerous vessels constructed in the northern and middle states; and for this purpose it would be difficult to replace it in North America." If Michaux had lived to the present day, he would not have failed to notice the vast use of pine and fir timber in railway construction. In the newly-cleared regions of America, and in many parts of Russia, corduroy roads, as they are called, are made of trunks of pine and fir, slightly dressed, and laid transversely to the length of the road.

Chips of some kinds of pine contain much resin or pitch, which render them useful as flambeaux in countries where candles and lamps are too expensive for the poorer cottagers. In one or other of the various kinds of pine and fir, all parts of the tree are made to render useful service. The fragments of wood yield fuel and charcoal; the ashes of the burnt roots, &c. furnish potash; the bark is useful in tanning; the buds and young shoots are made into spruce beer; the young shoots mixed with corn are food for cattle, sheep, and horses, in some countries; the inner bark is made into baskets; the long and slender rootlets furnish a kind of tough twine; the outer bark is used in Lapland and Russia for covering and lining huts, and as floats for fishing nets. The food of man is not without a supply from the fir and pine. The cones are sometimes used to flavour wine; the Laplanders make a coarse bread-flour from the inner bark; the kernels of some species are eaten as a substitute for hazel nuts, and are used in confectionary as a substitute for almonds; the kernels of one species yield much oil, useful both for food and for lamps; and the shells yield a rich dye.

Besides all the above useful substances, there are others yielded by these trees, due chiefly to the sap or juices. Common turpentine, Venice turpentine, Strasburgh turpentine, black resin, yellow resin, tar, common pitch, Burgundy pitch, lampblack—all are obtained, either from the living tree, or by the application of heat to the trunk and root when dead.

FIRE. [COMBUSTION; HEAT.]

FIRE (*Direct, Enfilade, Oblique, Plunging, Ricochet, Reverse, Slant*, or *Vertical*), are terms applied to the fire of a battery, according to its direction with respect to the object fired at.

Direct, when it is perpendicular to the face of the work or line of troops fired at.

Enfilade, when it is in the direction of the length of the face of a work or line of troops, or in the direction of the greatest length of a column or mass of troops. The battery will then be on, and ranged perpendicular to, the prolongation of such face of work or line of troops enfiladed.

Oblique, when it makes an angle with the front of the object fired at.

Plunging, when it is from a position higher than the object fired at.

Ricochet, when *enfilade* is with small charges. [RICOCHET.]

Reverse, when it strikes the interior slope of a parapet, or the rear of a line of troops, at an angle greater than 50°.

Slant, when it strikes the interior slope of a parapet, or rear of a line of troops, at an angle less than 30°.

Vertical, when the shot, having been fired at an angle of 45° or more, falls almost perpendicularly.

FIRE-ARMS. [ARMS; ARTILLERY.]

FIRE-BOTE. [COMMON, RIGHT OF; ESTOVERS.]

FIRE-DAMP. [METHYL, *hydride of*.]

FIRE-ENGINE, a term formerly applied to the steam-engine, but now confined to those machines which are employed to extinguish fires by throwing water from a jet upon the burning materials.

There were various modes of extinguishing fires previous to the invention of the modern fire-engine. A term employed by Juvenal and Pliny expressive of some implement used in extinguishing fires has given rise to some discussion. This term is Hama, which some commentators describe as a water-vessel; but Holstein contends that it was a very large hook or grapple fixed at the end of a long pole. Pliny the younger speaks also of pipes (siphones) being used to put out fires. Augustus appointed seven bands of firemen in Rome, each of which had the care of two divisions (regiones) of the city; each band had a captain (tribunus); and at the head of the whole body was the prefect of the watch (Præfectus Vigilum). With regard to such contrivances as might correctly come under the denomination of machines, it appears that they originated with Ctesibius, a distinguished Greek mechanician, who lived in Egypt in the reign of Ptolemy Philadelphus. Hero, a pupil of Ctesibius, describes a sort of forcing-pump with two cylinders, employed for the purpose of extinguishing fire. Apollodorus, architect to the Emperor Trajan, has left a description of a machine consisting of leathern bottles with pipes attached to them: when any bottle was squeezed, a jet of water flowed through the pipe, and was thus used to extinguish fires. Beckmann has found, in the accounts of many of the German towns, entries for the cost of machines, the existence of which would be very problematical without that evidence: thus, in the building accounts of the city of Augsburg for 1518, fire-engines are mentioned under the name of "instruments of fire," or "water-syringes."

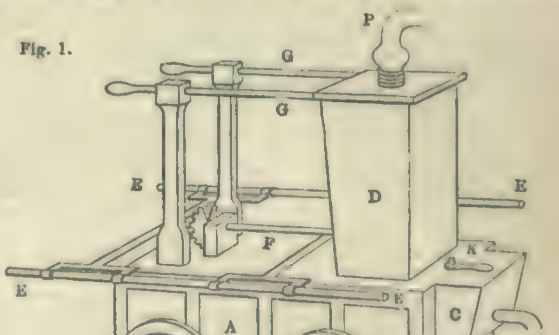
But the earliest account on which we can depend of a machine at all resembling those now in use is given by a Jesuit named Caspar Schott in 1657. This account related to a fire-engine made by Hautsch, of Nuremberg. It consisted of a water-cistern about 8 feet long, 4 feet high, and 2 feet in width; and was drawn on a kind of sledge somewhat larger than the cistern. It was worked by 28 men, and a stream of water an inch in diameter was forced, by means of this engine, to an elevation of nearly 80 feet. Schott supposed that it contained a horizontal cylinder, through which a piston worked, and thus produced a pump-like action. In 1699 the king of France gave a patent-right to Duperrier to construct fire-engines, under the name of *pompes portatives*, or portable pumps, and to keep them (17 in number) in repair and working order. Twenty-three years afterwards, the number of pumps amounted to 30, the management of which cost 20,000 livres annually.

There are two important parts of a fire-engine which do not appear to have been brought into use for some time after such machines became general: we mean the flexible hose or tube, and the air-chamber. Hautsch's engine, however, possessed the former, but not the latter. The purpose of a flexible tube is obvious, for it enables the operator to carry the stream of water in any direction from the engine; whereas without it the sphere of the engine's use is limited, from the impossibility of carrying the engine itself through narrow passages, &c. The air-chamber is a contrivance which depends for its value on the increased elasticity of air when compressed into less than its usual bulk. It is not exactly known who first applied this improvement; but an engine containing an air-chamber is stated by Perrault to have been kept for the protection of the king's library at Paris in 1684. The first introduction of them, however, for common use appears to have occurred about the year 1720, when Leupold constructed engines consisting of a copper box securely closed and well soldered: each one weighed about 16 pounds, and ejected a continuous jet of water to a height of 20 or 30 feet. This engine contained one cylinder and piston. The adaptation of leathern pipes was devised by two natives of Holland, both of whom were named Jan Vanderheide, and who were inspectors of fire-engines at Amsterdam in 1672. Five years after the invention, a twenty-five years' patent for the privilege of making those pipes was granted to them; and in 1695 sixty of them were kept in the city, of which six were to be used at each fire.

After the introduction of these engines into England, improvements were from time to time made in them, by Dickenson, Simpkin, Phillips, Furst, Newsham, Rowntree, Merryweather, Baddeley, Shand, Mason, and others; but from the time that the air-chamber was introduced the principle of construction has been nearly the same in all of them, the points of difference being principally in minor details. In briefly describing one of the old engines, therefore, on the construction of Newsham, we shall convey a general notion of the mode of action of most of them, without touching at present on the nicer points of difference.

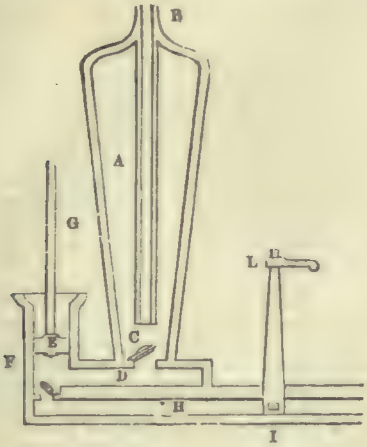
The body A (*fig.* 1.) incloses the greater part of the mechanism of the engine. Along the lower part runs a metallic pipe, into which the water flows from the feed-pipe B. If a supply of water cannot be obtained in this way, a cistern, C, is filled by means of buckets; and at the junction between the cistern and the interior pipe a grating or strainer is placed, to free the water from dirt, gravel, &c. The water having entered the interior pipe, is forced into the air-vessel by two pumps contained within the body of the box D, and from the air-vessel is forced into the pipe P, connected with the leathern hose by which the propelled water is directed to the proper point. The two pumps are worked by a double lever connected with two long handles, E E E E, which are conveniently placed for being worked by several men. The working is aided by one or two men, who stand on a cross-lever near F, and throw their weight alternately on each side, holding by the handles at G. At K, is a handle which turns a cock or valve, thereby regulating the supply of water to the interior pipe through the feed-pipe B. In *fig.* 2 we give a section through the middle of the air-chamber and one of the pump-barrels. A is the air-vessel, from the top of which proceeds nearly to the bottom a tube B C, open at both ends. The air-chamber and tube are in communication with a horizontal pipe, D, which opens by two branches into two pump cylinders, one of which is seen at F. Through this cylinder works the piston E, which is connected by the piston rod G with a toothed-wheel at the upper part; to which wheel a reciprocating motion is given by the exterior levers to which it is attached. The horizontal pipe D, besides its communication with the air-vessel and the pump-barrel, is also open to another horizontal pipe H, which is connected at the other end with the feed-pipe shown in the former figure. These communications however are closed at different parts of the operation by two

Fig. 1.



valves, one of which opens upwards from the pipe H to the pipe D; and the other also upwards from D to the air-vessel A. At the point I in the lower pipe is situated the cock, the handle of which is seen at L.

Fig. 2.



This being the relation of the parts to one another, let us now suppose the piston E and its rod G to have a reciprocating motion. The air chamber being full of air of the ordinary atmospheric density, we will suppose the piston to be drawn up to the top of the pump cylinder F. The piston draws up with it the air which the cylinder contains, and thus creates a partial vacuum beneath. The valve between the two pipes having now a stream of water pressing it upwards, while the space above it contains rarefied air only, the valve is forced open, and the pump-barrel F and the pipe D become filled with water. When the returning stroke of the lever forces the piston down to its former position, the water is driven before it into the air-vessel A. At the second upward motion of the piston a partial vacuum is again produced beneath it; but the water now contained in the air-vessel cannot return to fill that vacated space, on account of the mode in which the valve opens. A fresh supply is therefore gained, as before, from the pipe H through the valve communicating with D. This supply is, by the subsequent downward pressure of the piston, forced into the air-vessel, in the same manner as the first portion. The air in the air-vessel has no communication with the external atmosphere except through the pipe B C, which is fitted air-tight into the neck of the vessel at B. When the water ascends in this vessel above the bottom of the tube at C, the air above that level becomes compressed into a smaller space, as all escape is guarded against. With this compression its elasticity is also increased in the same ratio; and the effect of that increase is to drive the water up the tube. The velocity and height depend upon the compression; but as long as the density exceeds that of the external air, so long will the water be forced up the tube; and thus a continuous stream is insured, which is the object desired. If the condensation be carrried to a greater extent, the height to which the water will be ejected will increase in the same ratio; so that, if the bulk of the confined air were reduced to one-third, one-fourth, or one-fifth of its original bulk, the ascensive power gained would be about 66, 99, or 132 feet respectively.

Such are the simple principles of the old fire engines. It need hardly be said that improvements have since been introduced in every part. Contrivances are now used for preventing mud and gravel from entering the engine by the feed. Some engines, entirely of metal, have been made by Mr. Tilley. Merryweather's small or portable engines are provided for the special protection of public establishments and large mansions. The leathern hose or tubes, usually sewn up at the side, are sometimes fastened by means of metallic rivets. The Americans have devised a mode of weaving cotton tubes for engine-hose; a machine has been invented that will do this at the rate of 1000 feet per day; the tubes are only one-tenth the cost of leathern hose; and if two concentric tubes of this kind be cemented together with caoutchouc-solution, they are said to be even more durable than leather, and to require no oiling. Much ingenuity has been shown in devising a form of boss or nose for the end of the hose; the boss contains many small openings for the exit of the water; and Bramah, Baddeley, and other engineers, have so contrived these terminal pieces as to direct the play of the stream of water in any direction in a burning apartment. Captain Fowke's fire-engine, patented in 1859, dispenses with a cistern, and can hence be conveyed rapidly, on account of its light weight. It has a pair of single-action force-pumps, fitted with metal valves; a suction and delivery air-vessel; hose, to draw water into the pumps; and lever-handles, to force it out. It may be drawn by hand, or connected with a carriage drawn by a horse. A fire-engine of great power was made for the London Docks some years ago, with working barrels eight inches diameter; it would throw a jet eighty feet high, when worked perpendicularly. Many other fire-engines of great magnitude have since been constructed.

Mr. Braidwood, superintendent of the London Fire Brigade Establishment, read a paper before the Society of Arts, in 1856, in which he said:—"The description of fire-engines found to answer best in the metropolis are those with 7-inch barrels and 8-inch stroke, throwing, at the ordinary rate of working, about 90 gallons of water per minute. If a larger engine is thought desirable, two of these can be easily joined together in one stream, giving 180 gallons per minute. This size is preferred, because the weight, with hose, implements, firemen, and driver, is about 30 cwt., which is as much as two fast horses can manage for a distance under six miles. It is not often that the engines are required to travel further than this; when they are, four horses are used. For some years past, a hand-pump has been carried with each engine; they having been found of the greatest service in keeping doors, windows, &c., cool. They throw from 6 to 8 gallons per minute, to a height of 30 or 40 feet, and can be used in any position. The idea of these hand-pumps was taken from the old-fashioned squirt or hand-engine."

Down to the year 1825 all the Fire Insurance Companies of London had their separate establishments of fire-engines; but in that year the Sun, the Union, and the Royal Exchange Companies joined their fire-engine establishments, which were placed under one superintendence. Soon afterwards the Atlas and the Phœnix Companies joined the association. The advantage of this combined system of action having been proved, most of the remaining companies joined in 1833, and formed a new association, which was to be managed by a committee, formed by one member from each of the associated companies. London was divided into a certain number of districts, in each of which were two or more stations provided with engines. The plan has worked well: more companies have joined the association; and it is found that all are benefited. The firemen are formed into a corps, called the *fire-brigade*, which is under the efficient control of Mr. Braidwood, as superintendent. The men are clothed in a uniform, with stout helmets; and a certain number of them at each station are ready at all hours of day or night. Each company pays its quota towards the expenses of the fire-engine establishment. A very marked improvement has resulted in the capability and working of the engines. It may here be observed that, in by-gone years, the parishes of London provided fire-engines, under the compulsory provisions of two Acts passed in 1768 and 1778. About 300 of these small parish-engines still exist, but they render very little assistance at fires; it is found that the insurance companies, with their well-organised brigade, manage the business much better. The brigade now possesses about 30 large engines, and 10 or 12 smaller drawn by hand. It has a well-drilled staff of upwards of a hundred engineers, sub-engineers, firemen, and drivers. There are about twenty stations in the Metropolis, each with one to four engines, and a proportionate staff.

The remarkable aptness and celerity of the men composing the London Fire Brigade enable them to render an amount of service truly surprising. The police, cabmen, and poor persons out at night, are always ready to give notice at the engine-stations when a fire occurs—since they receive a fee for so doing; and thus the necessary intelligence is conveyed as quickly as in continental cities, where there are night-watchmen on elevated buildings to look out for fires. When the superintendent or foreman at any one of the twenty engine stations hears of the locality of a fire, five minutes' time is deemed sufficient to horse and away. Each of the large engines carries an engineer, four firemen, and a driver, besides the following apparatus:—several lengths of scaling-ladder, each 6½ feet long, all of which may be readily connected end to end, forming in a short space of time a ladder of any required height; a canvas sheet, with 10 or 12 handles of rope round the edge of it, to serve as a fire-escape; one 10-fathom and one 14-fathom piece of 2½ inch rope; six lengths of hose or leathern water-pipe, each 40 feet long; two branch-pipes, one 2½ feet, and the other 4 or 5 feet long, with a spare nose-pipe; two 6-feet lengths of suction-pipe; a flat rose, stand-cock, goose-neck, dam-board, boat-hook, saw, shovel, mattock, pole-axe, screw-wrench, crow-bar, portable cistern, two dog-tails, two balls of strips of sheepskin, two balls of small cord, instruments for opening the fire-plugs, and keys for turning the stop-cocks of the water-mains—the whole, with the men and the engine, weighing nearly 30 cwt.

On the Continent, and in America, the fire-engines are not managed, as in England, by fire-insurance companies; it is with them more of a government affair. In Paris, there are seven times as many firemen (*sapeurs-pompiers*) as in London, notwithstanding the smaller area and population; and yet the by-standers are compelled by law to aid in working the engines. In the United States, fire-companies of volunteers are formed in many of the towns; the members receive, not pay, but certain immunities from taxation and militia service. The annual parade-day of these companies is quite a fête, to which the fire-companies of other towns are invited, and at which competition trials of engines are made. Each company wears its own distinct uniform. Sometimes 36 companies of 50 men each have met. The prizes are usually awarded to the firemen of those engines which discharge a jet of water to the greatest height; in recent years a height of no less than 150 feet has been reached, by an engine with 10-inch cylinder. During the continuance of the Paris Exhibition in 1855, the engine-makers of

London, Paris, Canada, and the United States, placed between twenty and thirty large engines in competition, to test their powers for the satisfaction of one of the juries.

A few words must be said concerning the *steam* fire-engine. This was first employed at a fire at the Argyll Rooms, in London, in 1830, and displayed great power in throwing the water against the building. The furnace and boiler of this engine were similar to those of the 'Novelty,' a locomotive engine constructed by the same engineer for railway traffic. The pipe by which the water was jetted turned on a swivel, by which means the stream could be directed to any quarter. The cylinders were placed horizontally, and the steam-piston was connected with the water-pump plunger by a rod working through two stuffing boxes. This engine, the total weight of which did not exceed 45 cwt., consumed 3 bushels of coals in 5 hours, by which expenditure it was enabled to throw out from 30 to 40 tons of water per hour, which it propelled to a height of upwards of 80 feet, and on one occasion to 90 feet. Another engine, on the same construction, by Mr. Braithwaite, possessed 10-horse power (the former being about 6), and ejected the enormous quantity of 90 tons of water per hour. In 1832 a steam fire-engine was made for the king of Prussia by the same engineer, in which the steam could be got up in 20 minutes to a pressure of 70lbs. on the square inch. This engine ejected the water through a pipe 1¼ inch in diameter to the height of 115 or 120 feet: the number of strokes of the piston was 18 per minute, and the body of water ejected about 1¾ ton in that time. The power of steam was likewise applied to a *floating* fire-engine by Mr. Braithwaite, the machinery of which is so constructed, that the power of the engine can be at once changed from propelling the vessel to working the pumps, and thus do double duty. The London Fire Brigade Committee have recently turned their attention to this subject. Their first attempt was to alter a floating fire-engine which had been worked by manual power; and this was so well done, that the engine poured out 700 gallons per minute under a pressure of 70 or 80 lb. on the square inch. Another was thereupon constructed capable of throwing 1400 gallons per minute, and of moving at the rate of eight miles an hour, when propelled by the reaction of two jets 10 inches in diameter, driven by one of Appold's pumps. The vessel built for these engines is 130 feet long, with pumps and engines placed on the starboard and larboard sides of the midships. At Cincinnati large steam fire-engines have been for some years used; and the good service they render partly induced the London companies to revive and improve upon the old invention of Braithwaite. Competition trials of steam fire-engines have taken place in New York; one of them is said, at an extensive fire, to have poured out 15,000 barrels of water in 8¼ hours. Messrs. Shand and Mason have recently produced a new steam fire-engine in London, for use on land.

FIRE-ESCAPE. Numerous contrivances have been brought under public notice from time to time for saving the lives of persons who may be in a building while it is burning. Mr. Maseres devised a kind of chair of straps, by which a person could lower himself from a window. Mr. Davis, in 1809, proposed the use of three ladders, which might draw out like a telescope, and might reach from the ground to the upper windows of a house. Mr. Young, in 1813, contrived a sort of rope-ladder, with iron rounds of very flexible construction. Mr. Braby, in 1816, invented a sort of long pole, down which a car or chair might travel from a window to the ground. Mr. Witty, in 1820, introduced a sort of bag or case, which may be lowered from the sill of a window by ropes governed by a person seated in the bag. About 1835, Mr. Ford recommended the use of a long pole, at the upper end of which is tackle for lowering persons from a window; and soon after, Mr. Merryweather contrived a series of short ladders, which fit on to each other end to end, and can be elevated to a considerable height quickly.

But the fire-escape which has come most into use in London is a wheel-carriage supporting a lofty canvas shoot or trunk, attached to a ladder or frame; when placed up against a house, a person can get into this trunk from a window, and slide safely down to the bottom, with the aid of some ingenious mechanism attached to the frame. Many such machines are kept in public places in London during the night, attended by men whose business it is to wheel the machines to any spot where life is endangered by fire, and to work the machines.

A Report was presented to the city corporation in 1840 from the police commissioners, descriptive of thirty plans for fire-escapes, which had been proposed by different parties. They were of three classes:—1st. Machines intended for domestic use only, to be resorted to by inmates of houses in cases of fire; 2nd. Machines to be used from the outside, and made to combine the security of property with the protection of persons; 3rd. Machines exclusively for the protection of life from fire, to be used out of doors under the responsible direction of the police. Among the thirty were Davis's effective but rather ponderous machine; Wivell's, with the canvas trunk; and Gregory's sliding ladders on a carriage. It was considered that, whichever may be the best form in wide thoroughfares, the common fire-ladders carried with the engines of the London Brigade are the most generally useful in courts and confined situations. A suggestion was made in 1858, that it would be a good plan if in every house was kept a strong board with a hand-rail, and a hook at each end; by hanging one end outside the window of a burning house, and the other to the window of an adjoining house, a temporary bridge or balcony might be formed. Independent of other difficulties, however, there would always be the uncertainty of such a contrivance being in the right place at the right time. Another suggestion has been made, that each street or group of houses should possess a wire basket; that there should be a bracket fixed at the top of every house-front, projecting two feet; and that the police should be provided with some kind of rocket to send a rope over the bracket, and thereby haul up the basket. A third suggestion, of recent date, is that of Mr. Meakin; he proposes to fix two wire-ropes to strong hooks in the front wall of a house, to raise a kind of cradle on these ropes by means of pulleys, and then to govern the descent of the same cradle by the same ropes and pulleys.

None of the modern suggestions, however, as remarked above, are regarded as of equal value with the long ladder and canvas bag, used by the Society for the Protection of Life from Fire. The services rendered by this society can best be shown in reference to the nature and extent of London fires. Mr. Fothergill, of the Westminster Insurance Office, read a paper before the Institute of Actuaries in 1857, in which he presented a tabular view of all the London fires for twenty-four years, from 1833 to 1856. His object was to ascertain, if possible, the relative intensities of the causes of fire in each particular trade or occupation; with a view of rendering the return of annual fires by the London Fire Brigade Establishment in some way useful to the office-inspectors and surveyors of risks. His labours were much thwarted by the fact that two-thirds of all fires are attributed to "causes unknown." In those 24 years there had been 17,816 fires in London, or 742 per year on an average, or about 2 per day. Of these, in about 4 per cent. the premises were "totally destroyed;" 30 per cent. "much damaged;" and 66 per cent. "slightly damaged." Among the assigned causes of the accidents, some of the most peculiar were "thawing water-pipes"—"bottle of whiskey burst"—"sealing a letter"—"frying fish"—and "hunting bugs." The extent of the insurance principle may be illustrated in reference to the year 1856, when there were 1115 fires in London; of these, 318 had the buildings and contents insured, 106 the buildings only insured, 344 the contents only insured, and 347 wholly uninsured.

The society above named has provided fire-escapes in various parts of the metropolis. The operations first commenced in 1836, since which time fire-escapes have been established in new districts every year. There are now upwards of 70, situated about half-a-mile apart, each attended throughout the night by a conductor. Of the total number of fires (1114) in 1858, more than 500 were attended by the society's fire-escapes, and 57 lives saved by their means. At one of these fires one man saved no fewer than 9 lives. In the preceding year (1857) the society's men saved 73 lives; and in the whole period of operations 497,—a useful work for a society resting on no other basis than that of private subscriptions. The society has published the following description of the fire-escape employed, with sundry improvements lately introduced: "The main ladder reaches from 30 to 35 feet, and can instantly be applied to most second-floor windows by means of the carriage-lever. The upper ladder folds over the main ladder, and is raised easily into position by a rope attached to its lever-irons on either side of the main ladder; or, as recently adopted in one or two of the escapes, by an arrangement of pulleys in lieu of the lever-irons. The short ladder, for first-floors, fits in under the carriage, and is of the greatest service. Under the whole length of the main ladder is a canvas trough or bagging made of stout sail-cloth, protected by an outer trough of copper-wire net, leaving sufficient room between for the yielding of the canvas in a person's descent. The addition of the copper-wire is a great improvement; as, although not affording an entire protection against the canvas failing, it in most cases avails, and prevents the possibility of any one falling through. The soaking of the canvas in alum and other solutions is also attended to; but this, while preventing its flaming, cannot remove the risk of accident from the fire charring the canvas. The available height of these escapes is about 45 feet; but some of them carry a short supplementary ladder, which can be readily fixed at the top, and which increases the length to 50 feet."

FIRE, GREEK, an invention of the middle ages which was often employed in the wars of the Christians and Saracens. This subject has given rise to much inquiry and excited much discussion; the obscurity by which it is enveloped has been greatly increased by many causes, and especially by the love of the marvellous.

According to Gibbon the deliverance of Constantinople in the sieges of the 7th and 8th centuries "may be chiefly ascribed to the novelty, the terrors, and the real efficacy of the Greek fire. The important secret of compounding and directing this artificial flame was imported by Callinicus, a native of Heliopolis in Syria, who deserted from the service of the caliph to that of the emperor."

It is justly observed by Gibbon ('Dec. and Fall, ch. 52), that "the historian who presumes to analyse this extraordinary composition should suspect his own ignorance and that of his Byzantine guides, so prone to the marvellous, so careless, and in this instance so jealous of the truth. From their obscure and perhaps fallacious hints, it should seem that the principal ingredient of the Greek fire was naphtha, or liquid bitumen, a light, tenacious, and inflammable oil which springs from the earth, and catches fire as soon as it comes in contact with the air. The naphtha was mingled, I know not by what method or in what proportion, with sulphur and with the pitch that is extracted from evergreen firs." One of the properties here stated to belong to naphtha is well known to be, and indeed is, obviously incorrectly ascribed to it; if it were spontaneously inflammable it could not even be collected, and of course could not be mixed with the other ingredients which are named. Whatever may have been the precise nature of the mixture, the account of its effects, from which somewhat of the marvellous must be deducted, is thus strikingly portrayed by Gibbon: "From this mixture, which produced a thick smoke and a loud explosion, proceeded a fierce and obstinate flame, which not only rose in perpendicular ascent, but likewise burnt with equal vehemence in descent or lateral progress; instead of being extinguished, it was nourished and quickened by the element of water; and sand, urine, or vinegar were the only remedies that could damp the fury of this powerful agent, which was justly denominated by the Greeks the *liquid* or the *maritime* fire. For the annoyance of the enemy, it was employed with equal effect by sea and by land, in battles or in sieges. It was either poured from the ramparts in large boilers, or launched in red-hot balls of stone and iron, or darted in arrows and javelins, twisted round with flax and tow which had deeply imbibed the inflammable oil. Sometimes it was deposited in fire-ships, the victims and instruments of a more ample revenge, and was most commonly blown through long tubes of copper, which were planted on the prow of a galley, and fancifully shaped into the mouths of savage monsters, that seemed to vomit a stream of liquid and consuming fire." According to Gibbon, the secret of the Greek fire was confined above 400 years to the Romans of the east; it was at length either discovered or stolen by the Mohammedans, and in the holy wars of Syria and Egypt they retorted an invention contrived against themselves on the heads of the Christians. The *feu Grégeois*, as it is styled by the more early of the French writers, is thus described by Joinville: "It came flying through the air, like a winged long-tailed dragon, about the thickness of a hogshead, with a report of thunder and the velocity of lightning; and the darkness of the night was dispelled by this deadly illumination." The use of Greek fire was continued to the middle of the 14th century, when the more efficient employment of gunpowder was substituted. When Ypres was besieged by the Bishop of Norwich in 1383, the garrison defended itself with Greek fire. In a curious paper on the subject of Greek fire by the late Dr. MacCulloch ('Royal Inst. Journal,' vol. xiv.), he remarks that very different things were known by one name; and he supposes the various projectile means and combustibles employed to have been essentially different.

FIREPROOF CONSTRUCTION. A building is said to be *fireproof*, when it is constructed of incombustible materials; but it is essential to observe, that the danger arising from fire cannot be obviated entirely, even by the most theoretically or practically incombustible construction; and that consequently it is necessary, not only to observe the ordinary precautions against the destruction by fire of goods kept in such buildings, but also to guard against the effects of extraordinary heat upon the really incombustible materials of which the buildings themselves are formed. In the following notice, therefore, a description will be given of the materials which are the most fitted for the erection of fireproof buildings; and attention will subsidiarily be called to the danger and inconveniences to which they are exposed in actual practice.

The conditions required to be fulfilled by the materials to be employed in the erection of fireproof buildings are, that they should not only be unable to burn under the action of ordinary heat; but that they should also be, as far as possible, non-conductors of heat; that they should not expand or contract in a marked degree under the influence of changes of temperature, and that they should neither be exposed to fuse, nor to undergo chemical decomposition, when submitted to the action of fire. Of course all woods are excluded from the class of incombustible materials; but it must be evident, from the enumeration of the conditions those materials are required to fulfil, that the plasters, cements, limes, some varieties of bricks, and stones, cannot safely be trusted when they are likely to be exposed to great heats; and that the metals are equally objectionable, because they not only transmit heat readily and alter greatly in their dimensions, but also because sudden and great changes of temperature affect their powers of resistance, and even occasionally cause them to change their form entirely. The plasters and limes used in building owe their strength to the molecular adhesion originally produced by the solidification which takes place in the course of their hydration, and is subsequently increased by the gradual absorption of carbonic or sulphuric acid gas from the atmosphere. A very low temperature, comparatively, will suffice to destroy this state of combination, and to drive off both the gases and the water of crystallisation to such an extent as to destroy the cohesion of the mass. It is for this reason that the French plaster floors, or the English concrete floors (whether made with a lime or a cement base), are not able to resist the effects of great fires, although they may be sufficient to render ordinary dwellings practically fireproof; and for the same reason, brick vaulting itself is not entirely to be relied upon, when the area it covers is great, and there may be large quantities of combustible materials stored beneath it. Of the building stones, it would appear that the sandstones are more adapted for the purposes of fireproof construction than the limestones, because the latter become calcined under great heats; nevertheless, both limestones and sandstones are injuriously affected, both by the fire and by the water which is so profusely used on the occasions referred to. The sudden contractions produced by the application of cold water cause even granites themselves, about the most infusible of building materials, to fly, as workmen say, or to crack; and the same danger exists wherever metals are employed, even in a greater degree than when the less rapidly conducting materials are used.

It follows, from these considerations, that the security offered by any system of fireproof constructions must depend greatly upon the extent of the conflagration which may take place in them. As a fireproof building ought to be without any communication with surrounding buildings, and to have very small openings to the air in the majority of cases, it really acts in the manner of a retort upon the goods which may happen to be in combustion in its interior. It therefore is essential that the cubical capacity of any isolated incombustible compartment or building should not be large enough to allow a fire to take place which should be able to destroy the physical properties of the building materials employed; and it is to the neglect of this simple precaution that we may attribute the fact that whenever a fire does take place amongst the goods stored in incombustible buildings, the destruction of the goods themselves is entire, and that the stability of the building is so likely to be compromised. Some goods, such as cotton, wool, &c., are liable to spontaneous combustion; and if such goods should be stored in large quantities in one building, the security afforded by the supposed fireproof character of the materials of the latter will too often be found to be fallacious. Some of the most destructive fires have actually taken place in fireproof buildings; and nothing can be more striking than to observe the unaccountable changes of form produced in the iron, stone, or brick, exposed to the action of large masses of incandescent materials thus enclosed. Cast iron appears to be far more injuriously affected in these cases than wrought iron, especially when it is likely to be suddenly chilled by the cold water pumped upon the burning goods. Wrought iron, however, loses its elasticity when heated, and is exposed to change its form under the action of loads it would otherwise have easily supported.

These remarks apply especially to warehouses; but in ordinary house or shop construction it rarely happens that a sufficient quantity of goods is contained in any one compartment of the building to entail any extraordinary danger. If, therefore, the walls of such houses be built of good brick or stone; if iron be used instead of wood for girders, lintels, bressummers, &c.; if the roof be entirely of metal, and the floors of either brick-work, tiles in cement, stone landings, or of plaster or concrete; the houses will be, for all practical purposes, fireproof. These materials are, however, all of them good conductors of heat; and, as such, they require, in dwellings, to be covered with wood, or some other material which should be able to obviate the unpleasant feeling produced by their being exposed. The danger of the combustion of such woodwork may be materially diminished by the application of a soluble glass to all the exposed surfaces; and care should be taken that none of the wood runs so far into the solid walls as to affect their stability, either in consequence of its being burnt out, or on account of the chemical changes produced by the heat. The resinous woods being more rapidly inflammable than oak, or the harder woods, such as mahogany, teak, rosewood, &c., are less fitted for the purposes of lining fireproof structures than are the latter; and it is perhaps on account of the general use of oak floors in Paris that so few fires occur in that town, in comparison with those which occur in London, where fir floors are almost exclusively used. It may be added, that one of the greatest sources of danger in ordinary house building arises from the use of wooden staircases, which serve to conduct the fire from one floor to another. As a general rule, moreover, it will be found that the thickness of party walls which is requisite to ensure the statical stability of a building will be sufficient to prevent the communication of any ordinary fire from one house to another: provided always that no timbers be allowed to be inserted in such walls, or at least that solid non-combustible materials of at least nine inches in thickness shall always be placed between the ends of the timbers thus let in. Great care should be taken, when artificial methods of warming are adopted, to isolate the timbers or joiners' work from the pipes or passages by which the heat is distributed; for the effect of the proximity of wood-work to such heat passages is to dessicate the wood thoroughly, and to render it highly inflammable. The same remark would of course apply, *mutatis mutandis*, to the combustion of gas near wood-work; and it is desirable in all these cases that a sufficient non-conducting cushion of air should be, as it were, interposed between the source of heat and the wood-work.

FIREPROOFING. In this article we shall briefly describe three modes of shielding combustible articles from the ravages of fire, under the sub-headings *Fireproof Repositories*, *Fireproof Woodwork*, and *Fireproof Textile Goods*.

Fireproof Repositories.—By this we do not mean houses or buildings, rendered fireproof by peculiar modes of construction; these are treated in another article. [FIREPROOF BUILDINGS.] We speak of iron chambers, coffers, or boxes, for containing valuable property. It was not until the present century that such receptacles were regularly and systematically made. A few may have been constructed as special examples of ingenuity; but the manufacture had not yet become a regular branch of trade. The old treasure-receptacles were oak chests, secured by one or more locks, or brick or stone closets, with wooden doors studded with nails, and fastened by locks, or staples and padlocks. The crown jewels of Scotland were placed in a strong oak chest in the year 1707; it had three locks, and when required to be opened in presence of a body of royal commissioners in 1818, it had to be forced, on account of the loss of the key or keys. Iron coffers of elaborate construction were known on the Continent before being common in England,—possibly on account of the system of hoarding treasure, more customary in countries where commercial enterprise is languid. Wolverhampton, Birmingham, and Coalbrook Dale began the manufacture of cast-iron safes; London alone made those of wrought iron till 1835, since which year they have been made also in the north. These safes, however, were not in the first instance put forth as fireproof; there was nothing to prevent them, when red-hot, from burning the papers and charring the parchments inclosed in them. It was in 1834 that the fireproof principle appears to have been first adopted, under Marr's patent. Since that date, Bramah, Chubb, Milner, Hobbs, Price, Tann, and other manufacturers have brought great ingenuity to bear on this subject. There are several requisites for a good fireproof safe. The iron should be of such a thickness as to prevent the safe from being broken open by violence, or injured by a fall or other casualty during a fire. The door should be so closely fitted that no forcing instrument could be introduced between its edge and the framework into which it closes. The iron plates should be so prepared as to resist the action of drills, whether made for the purpose of taking out the small lock or of inserting gunpowder to shatter it. The large lock should be so made that, even if holes were drilled through the door, no space would be found inside the case to contain sufficient gunpowder to explode it. The case containing the lock should fit the interior of the safe as tightly as possible, to exclude the external heat in case of fire and the escape of the moisture from the fire-resisting composition within. The inside case, forming chambers for containing the fire-resisting substance, should fit the inside of the body tightly, to prevent the undue escape of the vapour when in a fire; this case, also, should be so secured to the outer frame that no violence exerted on the door would force the removal of the lining or casing. The fire-resisting composition should be of such a nature and should be so placed as not to exert any injurious effect upon the iron when heated. It need hardly be added, that the large lock which closes the door, and the small lock which secures the bolt, should be free from liability to disarrangement, likely to wear well, and not easily picked. All the modern fireproof safes contain a sort of lining of fireproof composition, which has a remarkable effect in arresting the progress of heat from without inwards. Of course no safe could resist an unlimited heat for an unlimited time; but the modern makers are very successful in manufacturing safes which will preserve their contents unharmed during the destruction by fire of the building in which the safe is placed. There is an absorbent substance, such as sand or sawdust, and there are small vessels containing some kind of liquid; the heat from an external fire, acting on the liquid through the iron, bursts the vessels, saturates the absorbent substance, and greatly retards the heating of the interior. Some of the safes are painted on the inside with a peculiar composition, to prevent the metal from being oxidised or corroded by the action of acids employed to produce the moisture; and the exterior of the iron is case-hardened, or rendered like steel, to enable it to resist the action of drilling-intruments. Triple thicknesses of iron, mica linings, vitreous glazings,—all are used in different forms of safe; and the absorbent composition used for a stuffing or damper exhibits great variety,—burnt clay, powdered charcoal, dust, fragments of stone, baked wood ashes, coarse sand, small gravel, sawdust, bone-dust, ground alum, gypsum, Austin's cement, combined two or more together, with or without provision for moistening them when heated.

Some of these fireproof receptacles have recently been constructed of great magnitude. One was made by Messrs. Chubb in 1858 for the Vancouver branch of the Bank of British North America. It was 7 feet high, 9½ feet deep, and 7 feet wide. It was made of wrought iron, lined with a fire-resisting composition. It was, in fact, a chamber, containing nineteen separate and distinct lock-up safes, besides shelves for books and papers. On the exterior it had two large folding-doors, having three detector locks, and throwing thirty bolts all round. The various pieces, weighing 14 tons in all, were sent out separated, to be built up at the place of destination. A partner in this firm, after the disastrous loss of the gold-laden ship Royal Charter, wrote to one of the public journals in the following terms:—"In ocean-ships the bullion-room is usually formed by lining some nook or corner with strong iron-plates, bolted to, or forming part of, the ship; so that if the vessel gets on shore and breaks up, the bullion-room necessarily goes to pieces with it, and the contents are dispersed. I would suggest that these safes should not be in any way connected with or fixed to the ship. In case of a wreck or breaking up of the vessel on shore, the safe would go to the bottom, preserve its contents intact, and be readily recovered. As a safe four feet square will hold more than 2,000,000*l.* sterling, very little space would be interfered with."

A London solicitor, in a letter to the 'Times,' has pointed out the desirability of having, somewhere near the courts of law and inns of court, a public or joint-stock institution for the safe custody of valuables from fire and depredation. "The main features of my plan," he explained, "would be to erect two or three fireproof buildings in so many localities in London, most convenient to professional gentlemen and others who may avail themselves of these advantages; and to have in each building separate strong rooms for any persons wishing to have the exclusive use of them; and also other places for depositing deeds, securities, plate, &c., on the responsibility and under the guardianship of the managers." It is supposed, according to this suggestion, that an adequate rental would willingly be paid for such fireproof strongholds.

Fireproof Woodwork.—In the article ANNIHILATOR, FIRE, a description is given of a mode of extinguishing fire by means of chlorate of potash mixed with sugar—not used as a liquid to protect woodwork, but as a gas which stifles the flame. We have now to notice a process which has recently occupied much attention. Many liquids have been devised from time to time, for making wood more or less fireproof. A mere coating of lime-wash will do something towards this end; and a wash or cream of clay in water will act nearly in the same way. In Maugham's patent process, dry wood is saturated with an aqueous solution of phosphate of soda and muriate or sulphate of ammonia; the theory or expectation being, that a decomposition will ensue, followed by an evolution of ammoniacal vapour, and the formation of an incombustible coating on the surface of the wood. Jackson's patent consists in the application of a solution of salts of zinc and ammonia. Salomon's patent consists in a peculiar application of two solutions to the surface of wood; the first consisting of sulphate of alumina, glue, and water; and the second of chloride of calcium, glue, and water.

The substance which is now attracting most notice, in connection with this subject, is silicate of soda. Mr. Abel, chemist to the War Department, and Mr. Hay, chemist to the Admiralty, made experiments on this salt in 1857. A wooden hut, similar in construction to those at Aldershott Camp, was set up at Woolwich Marshes. The immediate purpose in view was to test Phillips' Fire Annihilator; but advantage was also taken of the opportunity to try the efficacy of the silicate of soda as a protector. The officers of the Royal Engineers suggested that if a *part* of the hut were thus treated, the result might afford materials for comparison. This was done. One portion of the hut was painted inside and out with a mixture of lime and alum; this was not found to act as a sufficient protector against fire. Another portion was then painted inside and out, three times, with a solution of silicate of soda. Unfortunately for the fairness of the experiment, the building was constructed with a double boarding; so that it was only possible to coat or impregnate each plank on one side. Nevertheless, the value of the silicate was established beyond a doubt. A large heap of shavings was lighted in the interior of the hut, against the coated portion of the woodwork. The flame played fiercely against the timber for some minutes, but only succeeded in kindling the edge of one plank; and even that did not blaze, but only smouldered for a short time. By the heat of the fire the salt was drawn to the surface of the wood, and fused, forming a glaze upon it. Subsequently, when the whole hut was destroyed by fire, after unsuccessful attempts to extinguish it by the annihilator, although the fierceness of the flame was such that few materials could have withstood it, yet several planks remained of the exterior coated portion. Upon examining these planks, the unprotected surfaces were found to be completely charred; but this charring had extended only to those parts which had not been touched by the silicate. So far as experiments have yet gone, this salt appears to be the most convenient and effective known for the purpose.

Fireproof Textile Goods.—Attempts are now being made to impart something of the nature of non-inflammability to the muslin and other light materials of which ladies' dresses are made. Very lamentable calamities from fire have drawn attention to the subject; and at the Aberdeen Meeting of the British Association, in 1859, certain experiments were described which had been made by Messrs. Versmann and Oppenheim. It has long been known that cotton and linen fabrics may be partially protected from fire by a solution of alum or of common salt; but the alum weakens the fibres, and the salt makes them harsh and crisp—faults which greatly lessen the value of the processes. Experiments showed that borax will exert a considerable preservative effect, but that the material is weakened thereby as with alum. It was next found that phosphate of ammonia exerts the preservative effect without that of weakening; but here occurred a new difficulty: the salt becomes decomposed under the heat of the laundress's iron. Sulphate of ammonia, only one-fourth the price of the phosphate, was next tried; it had most of the merits and the one defect of its predecessor. Messrs. Versmann and Oppenheim at length hit upon the tungstate of soda, as a salt which, in solution, imparts a considerable degree of non-inflammability to textile or woven fabrics, without weakening them, or rendering them harsh and stiff, and also without liability of having the preservative properties removed by heat or by washing. Since the Aberdeen meeting, the inventors have arrived at a conclusion that the cheap sulphate of ammonia will suffice in factories on general woven goods; but the tungstate of soda is better for domestic use, where the fabric is likely to be afterwards ironed. It is evident, from this enumeration of chemical agents, that others of superior efficacy may probably be discovered. A new process has just been announced, the invention of M. Carteron, of Paris, which will render silk as well as cotton and linen fabrics incombustible, but the method has not been published.

FIRE SHIPS. Among the peculiarities of naval warfare may be instanced the use of fire ships, a class of vessels which are so fitted with inflammable and combustible substances, as to take fire in all parts simultaneously on the lighting of an attached fuse, the length of the fuse being adapted to the occasion, and so as to allow sufficient time to elapse after ignition to enable the firing party to effect a safe retreat from the conflagration.

Fire ships are at all times a formidable means of attack, but especially so when darkness or fog favours their employment. They are used principally in rivers or roadsteads against ships at anchor. The Chinese in the late war showed considerable ingenuity in availing themselves of this mode of surprise and attack, in which so little exposure of life on their side, enabled them to threaten with destruction a more powerful enemy; and but for great vigilance on our part, much disaster to our ships must have resulted. The nature of improved armaments, however, tends materially to protect ships at anchor from attempts of this kind; for immediately on the detection of a suspected fire ship, the increased precision of aim, the heavier weight of shot, and the progressing improvement in naval tactics now developing, will enable a threatened ship rapidly to destroy and sink any of the class of vessels generally used as fire ships, or will disperse into fragments the framework and materials of fire rafts.

So long as 150 years since, fire ships formed part of the regular establishment of the naval defences of the kingdom. In the 'Navy List' of 1710, we see the names of five of these vessels, each of which was armed with 8 guns, to be used either for ordinary battle, or in setting fire to an enemy, as opportunity might offer. Of late years, however, their use has been confined solely to the defence of invaded coasts. No ships of this class are now to be found in the English navy. Every gunner in the sea service is trained according to an approved system on board H.M.S. Excellent, to so dispose of combustible matter, fuses, &c., as to readily convert any vessel into a fire-ship.

(*Magnæ Britanniæ Notitia*; Sir Howard Douglas *On Naval Warfare with Steam, &c.*)

FIRKIN, a measure of ale, beer, and some dry commodities now disused. Eight gallons of ale, soap, or herrings, made a firkin, and nine gallons of beer. But by a statute passed in 1689, the distinction between the firkin of ale and beer was abolished, except only in London, and eight and a half gallons were declared to make a firkin. In 1803 the ale and beer measures were ordered to be assimilated, and the firkin now contains nine gallons.

FIRM. [Partnership.]

FIRMA'N or **FIRMAU'N**, is the name of the decrees issued by the Turkish Sultan, which are signed with his own cipher or signet. Such are the firmauns by which he appoints the various pashas and other great officers of the state. Firmaun is also the name of a kind of passport which the pashas are in the habit of granting to travellers, especially Europeans, by which they enjoin the subordinate authorities to give the bearer protection and assistance. The "firmaun of death" was a sentence of summary execution issued by the sultan against a pasha, the written order for which was entrusted to a chiaous, or state messenger, whose duty it was to see it executed.

FIRST FRUITS (Primitiæ), the profits of every spiritual living for one year, according to the valuation thereof in the king's books [Annates]. They were claimed by the pope throughout Christendom, his claim being first asserted in England in the reign of King John, and then only so far as related to clerks whom he appointed to benefices. Afterwards, by Pope Clement V. and John XXII., about the beginning of the 14th century, they were demanded from all clerks, by whomsoever presented. By 25 Henry VIII. c. 20, and 26 Henry VIII. c. 3, first fruits and tenths [Tenths] were given to the king. In the thirty-second year of the same reign a court was erected for the management of them, but it was soon after abolished. Queen Anne gave up the first fruits to be applied towards the augmentation of small livings. [Benefice.]

First fruits arising in Ireland were by Geo. I. c. 15, to be applied for the same purpose; but by the 3 & 4 Will. IV. c. 37, the payment of first fruits in Ireland is abolished.

FISC, FISCUS, was the name given under the Roman empire, and afterwards in the monarchies which rose on its ruins, to the private treasury of the sovereign, as distinguished from ærarium, or the treasury of the state. The fiscus was chiefly replenished by fines and confiscations, and unclaimed property of deceased persons: the taxes and other revenues of the country were paid into the ærarium. Under absolute monarchies, however, the two treasuries have been often confounded both in name and in reality. Under the feudal system, fiscus regius and fiscales terræ signified the domains of the crown, and the peasants attached to those domains were called fiscalini. Fiscus by degrees came to be used figuratively for the rights of the crown in civil as well as criminal matters, and the king's attorney was called procurator fisci, procureur fiscal in French, avvocato fiscale in Italian. Fiscus, in the sense of "feudum regium," or fiefs granted by the crown, was contrasted with proprietas, or an allodial estate. The word fiscus meant originally a basket or frail in which the moneys of the prince were collected. (Ducange.)

FISHERIES are localities frequented at certain seasons by shoals or great numbers of fish, where they are taken upon a large scale. The right of frequenting these fishing-grounds has frequently been matter of dispute between governments, and sometimes the subject of treaties; while exclusion from them, or invasion of presumed exclusive rights to their enjoyment, has been the cause of warlike preparations. The principal kinds of fish which are the objects of these systematic occupations are whales, cod, ling, hake, herrings, lobsters, mackerel, oysters, pilchards, salmon, anchovies, sardines, sturgeon, and tunny. With the exception of the four last-named descriptions, the fishermen of this country are engaged in the taking of all these fish, and pursue their calling to an extent which makes each an important branch of national industry. The quantity of other fish taken by British fishermen is in the aggregate exceedingly great, and furnishes constant employment throughout the year to a great number of men on almost every part of the coasts of Great Britain and Ireland; but it has not been usual to apply the word fisheries otherwise than as we have already mentioned.

Of the British fisheries, some are carried on in rivers or their æstuaries, and others in the bays or along the coasts. Our principal cod-fishery is on the banks of Newfoundland; and for whales our ships frequent the shores of Greenland, Davis's Straits, and the South Seas. Of late, whale-fisheries have also been carried on near the shores of Australia and of the Cape of Good Hope.

The taking of herrings was extensively pursued in Scotland in the ninth century, and continued until the Convention of Royal Burghs prohibited the exportation of fish before the resident population was supplied at a stipulated price. In consequence of this interference, many of the fishermen abandoned the pursuit at home, and settled in Holland—a circumstance which first drew the attention of the Dutch to the value of the Scotch fisheries. Several enactments were passed under James III., IV., and V. of Scotland for the promotion of the fisheries; and James VI., before his accession to the English throne, directed the building of three towns for the same purpose; but this measure failed of success. In 1633 Charles I. ordained "An Association of the three kingdoms for a general fishery within the hail seas and coasts of his majesty's said kingdoms," but the breaking out of the civil war put an end to this scheme. In 1654 the government, in order to give protection to the fisheries, remitted in favour of Sir Phineas Andrews, who had embarked in the same, the salt duties and "customs, and excise duties upon all naval necessaries;" besides which, voluntary collections were made from wealthy and patriotic individuals for building wharfs, docks, and storehouses, and for defraying other expenses. These measures of "protection" appear to have been unsuccessful; as were others of various kinds, made in 1677, 1690, and 1720, sometimes through the medium of charters, sometimes through that of Joint-stock companies. Various reasons have been assigned for these repeated failures. Among these reasons may be mentioned, the rule which made London the head-quarters of the fishery (it being the dearest port in the kingdom) and the superiority of the Dutch in the art. Andrew Yarington, in the second part of "England's Improvement by Sea and Land," sums up all other reasons in this one fact—"We fish intolerably dear, and the Dutch exceedingly cheap." In 1749 a committee of the House of Commons was appointed to inquire concerning the herring and white fisheries: and as the result of its labours a corporation was formed, with a capital of 500,000*l.*, under the name of "The Society of the Free British Fishery." A bounty was given to encourage the fishermen, increased in amount from time to time; but this entirely failed in realising the object in view; for, the bounty being given to the vessels and not to the fish, "ships were equipped to catch the bounty and not the herrings." In 1786 "The British Society for extending the Fisheries and improving the Sea Coasts of the Kingdom" was incorporated, and a joint-stock was subscribed "for purchasing land and building thereon free towns, villages, and fishing-stations in the Highlands and Islands of Scotland." This joint-stock was raised by the subscriptions of a few spirited individuals, who did not look for any profitable return. The members of the society were chiefly proprietors of estates, and their object was the improvement of their property. Another act was passed in 1808 for the regulation of the fisheries: granting bounties to the fishermen; and prescribing regulations for fishing, curing, inspecting and branding herrings, and a board of seven commissioners was appointed for administering the law. This act, which was at first passed for a limited time, was made perpetual in 1815. For the inspection and branding of herrings the whole coast of Great Britain was divided into districts. In each of these officers were appointed to oversee the operations of the fishermen, and to prevent frauds in regard to the bounty. The principal regulations affecting the curing of herrings were borrowed from the practice of the Dutch fishermen. In 1817 a further boon was granted to the fishermen by allowing them the use of salt duty free: a peculiar advantage, which ceased in 1823 by the repeal of the duty on that article.

The impolicy of granting bounties on production, the effect of which is to tax the people of this country in order that foreign countries may be supplied with articles of consumption at prices below their actual cost, came at length to be seen and acknowledged. In 1821 the bounty began to be reduced, and in 1830 it ceased altogether. That this alteration of the system has not been productive of any serious evil to the herring-fishery has been abundantly shown by the statistical returns. The average annual number of barrels of herrings cured and exported respectively in the five years that preceded the alteration was 349,488 and 224,370. In the five years from 1826 to 1830, while the bounty was proceeding to its annihilation, the average numbers were 326,896 cured, and 208,944 exported; and in the year 1858, the numbers were 636,122 barrels cured, and 350,204 exported. An end appears to have been put to the protective system by the British Parliament, in the 10 & 11 Vict. c. 91, withdrawing altogether the funds granted year by year for the promotion of the Scotch fisheries; and, in the 21 & 22 Vict. c. 69, exacting a fee for every barrel or half barrel of herrings on which the government brand is imposed, a valuable advantage that had heretofore been conferred on these traders altogether at the public expense. The same act repeals sundry vexatious provisions of previous statutes which had impeded the trade and increased the expense of the traffic without any advantage in return; it prohibits the use of certain nets and certain methods in taking the fish; it prescribes a uniformity in measures; and thus surrenders the traffic to the fostering care of private interest and the salutary effect of public competition.

The Irish fisheries generally continue still to be stimulated by public grants from time to time, without any intention thereby of giving effect to a policy which experience and principle have condemned, but to meet the unfortunate circumstances of that country by furnishing immediate employment to the poor in a traffic more legitimate than the making of public roads that are not wanted, inasmuch as it may become remunerative to the fishermen, and advantageous to the public without the need of extraneous support.

A select committee of the House of Commons was appointed in 1833 to inquire into the state of the British Channel fisheries. A second committee was appointed in 1836 to consider the state of the salmon fisheries in Scotland; and in the previous year commissioners had been instructed to investigate the condition of the Irish fisheries. From each of these bodies reports proceeded which were laid before Parliament, and which contained a considerable amount of information upon the subject. We will present here a few of the leading facts, corrected by the results of inquiries of later date.

The appointment of the committee in 1833 arose out of the distress which was at that time said to affect the several Channel fisheries, and in its report the committee stated that these fisheries were generally in a very depressed and declining state; that they appear to have been gradually sinking since the peace in 1815; that the capital employed did not yield a profitable return; that the number of vessels and of the people to whom it gave employment had diminished; and that the fishermen who formerly could maintain themselves and their families by their industry were in a greater or less degree pauperised. The chief causes of this unfavourable change were considered to be, the interference of the fishermen of France and Holland; and the great and increasing scarcity of all fish which breed in the Channel, compared with what was the ordinary supply 15 to 20 years earlier, operating prejudicially to the fishermen, at the same time that a continued fall of prices had taken place in the markets. The depressed state of the British fisheries is most easily explained by supposing that the foreign fishermen, of whose interference such grievous complaint was made, were better skilled and more persevering in their calling than our own countrymen: a supposition which seems to be borne out by the circumstance of our having, since this report was delivered, been still more abundantly supplied with fish for our tables; while the cry of distress on the part of the fishermen has passed away, doubtless owing to the greater degree of skill and industry which they have since exerted. There was, on the other hand, a complaint preferred against the fishermen by the owners of the boats, who alleged that, having advanced all the capital necessary for the undertaking, and having probably also contributed to the support of the men during the dead season, under the faith of an agreement to receive at stipulated prices all the produce of their nets, the men so bound to them sold a considerable part of the fish which they caught to boats despatched from the coast of France. These circumstances have been mentioned, because a great and it is thought a groundless impression was created by the result of the inquiry of 1833, which inquiry, it has been alleged, was undertaken to satisfy the desires of certain interested parties who wished to make out a case for the interference of government.

These Channel fisheries have been the occasion of much jealousy between England and France, and of continual wrangling between the fishermen of the two countries; they were at length, in 1839, made the subject of a convention between the two governments, and the stipulations contained therein have been embodied into the law of this country successively by the 6 & 7 Vict. c. 79, and the 18 & 19 Vict. c. 101.

Stow-Boat Fishery.—One peculiar branch of fishery is the Stow-boat fishery. This fishery prevails principally upon the Kentish, Norfolk, and Essex coasts; and the object is the catching of sprats, not for food, but as manure for the land, for which there is a constant demand. It fluctuates considerably, according to the price of other agricultural manures, and to the abundance of the shoals of fish.

Pilchard Fishery.—The pilchard fishery, which is carried on upon parts of the Devon and Cornish coasts, is of some importance. The pilchards visit our shores in August and September, and again in November or December: they come in large shoals into shallow water. As soon as caught they are salted or pickled and exported to foreign markets, chiefly to the Mediterranean: the average export amounts to 30,000 hogsheads per year.

Herring Fishery.—The extent of the British herring-fishery has already been noticed. The places where it is principally carried on are Yarmouth, Lowestoft, Hastings, Folkestone, Cardigan Bay, and Swansea, in England and Wales; the coasts of Caithness, Sutherland, Aberdeenshire, Banffshire, Morayshire, and Ross-shire, in Scotland; and Galway, Killybegs on the coast of Donegal, Mayo, the æstuary of the Shannon, the coast between Dingle Bay and Kenmare, Bantry Bay, Waterford, and from Mizen-head to Cahore point on the Wicklow coast, in Ireland. The principal herring-fishery off the coast of Norfolk and Suffolk commences in September and ends in the beginning of December. Mackerel fishing begins 1st May, and ends 1st July. No material changes have occurred in the seasons, but herrings are more numerous of late years on the Yorkshire coast.

Salmon Fishery.—Our chief salmon-fisheries are carried on in the rivers and æstuaries of Scotland. As no bounty has been at any time payable upon the taking or exporting of this kind of fish, there are no means of ascertaining its actual or comparative amount. Great interest and activity have in recent years been evinced by noblemen and the landed gentry, with much success, in promoting the breed of salmon, and the protection thereof has long been an object with the British Parliament, who by various Acts, 1 Geo. I. c. 18; 58 Geo. III. c. 43; 6 & 7 Vict. c. 33; and 11 & 12 Vict. c. 52, have prescribed certain regulations, and prohibited the taking of fish at certain periods of the year, with the same end in view. The produce of the fishings in the rivers Dee, Don, Spey, Findhorn, Beauly, Borriedale, Langwell and Thurso, and of the coasts adjacent, are conveyed in steam-boats and small sailing vessels to Aberdeen, where they are packed with ice in boxes and sent to the London market, either by steamers or by railway. The most productive salmon-fisheries in Ireland are situated near the mouths of the rivers, on nearly all parts of the coast.

Mackerel Fishery.—Mackerel are fish of passage which visit every part of our coasts in the spring and early part of the summer, and are taken in great abundance. In this country they are used fresh, and great quantities are conveyed by rapid railway journeys from the coast to London. The general desire to obtain this fish in perfection has led to the well-known relaxation of our laws against Sunday trading, which permits the open hawking about of mackerel on that day: a practice which is punishable with regard to any other fish, or indeed to articles of any kind, with the exception of milk.

The principal fisheries on the eastern coast of England are in the neighbourhood of Whitby, Hartlepool, and Robin Hood's Bay. The fish-markets of the great towns in the interior are now supplied more abundantly than ever with fish, through the agency of railways.

Cod Fishery.—The cod fishery at Newfoundland was carried on as early as 1500 by the Portuguese, Biscayans, and French; but it was not until 1585 that the English ventured to interfere with them. In that year Sir Francis Drake, being sent to the island with a squadron, seized the foreign ships which he found engaged in the fishery, and sent them to England, where they were declared lawful prizes. In 1610 a company was incorporated for the same purpose by King James I., and so successfully was the fishery prosecuted, that in 1614 there were near 200 vessels engaged in it; in the following year the number exceeded 250. The English fishermen were, however, closely pressed by those of France, who had sundry advantages in their favour. By the treaty of Utrecht, which acknowledged the sovereignty of the whole island of Newfoundland to be in the crown of England, the privilege of fishing on part of the coast was reserved to France, notwithstanding which the English fishery there increased to a great extent. The resort of the United States fishermen to the coasts of Newfoundland for the purpose of sharing in this remunerative traffic began early to excite the jealousy of the British fishermen, and the quarrels arising in consequence appealed so strongly to the peculiar sympathies and pride of the respective countries, that armed vessels were sent to the fishing-ground, nominally to preserve peace and order, and serious apprehensions were created as to the possibility of maintaining the peaceful relations between the two governments. At length a treaty was concluded in 1854 between England and the United States, and the stipulations of it became the law of this country by the 18 & 19 Vict. c. 3. By this treaty, the right of taking all kind of fish except shell-fish, and curing and drying fish, is granted to the fishermen of the United States on the sea-coasts, shores, bays, and harbours of Canada, New Brunswick, Nova Scotia, Prince Edward's Island, and with some modification, Newfoundland. The principal fisheries of Newfoundland are prosecuted on the banks which nearly surround that island; the object of these fisheries is solely cod-fish. Salmon, mackerel, herrings, and some other kinds of fish are taken off the coasts of the island; and the seal fishery is carried on successfully, yielding a considerable number of seal-skins and a large quantity of seal-oil for exportation. These fisheries may be said to be the sole pursuit of the settlers in Newfoundland, and of the traders who frequent the island. Nearly every family has a small piece of land under garden cultivation, but agriculture is not pursued as a substantive occupation.

Whale Fishery.—The whale fishery was carried on successfully during the 12th, 13th, and 14th centuries, by the Biscayans. The whales taken by them in the Bay of Biscay appear to have been of a smaller species than those since found in more northern latitudes. The Biscayan fishery has long ceased, owing probably to the great destruction of the animals. It is to the voyagers who, near the end of the 16th century, attempted to find a passage through the northern ocean to India, that we owe the discovery which led to the establishment of the fishery in the seas of Greenland and Spitzbergen. The English and the Dutch were the first to embark in this adventure; but the French, Danes, Hamburghers, and others were not slow to follow their example. At first the whales were so numerous that the fishing was comparatively easy, and was so successfully pursued that, in addition to the ships actually engaged in the fishery, many other vessels were sent in ballast to the shores of Spitzbergen, and the whole returned home with full cargoes of oil and whalebone. It was then the practice to boil the blubber on the spot, and bring home the oil in casks. In the progress of the fishery the whales became less numerous, and, when found, more difficult to take. It therefore became necessary to pursue them farther to the open sea, and at length it was found more economical to bring the blubber home in order to its being boiled, and the settlements before used for that purpose were abandoned. That part of the Arctic Sea which lies between Spitzbergen and Greenland, and which was formerly frequented by the whale ships, is now almost wholly abandoned because of the scarcity of the fish, and the northern whale fishery is now chiefly pursued in Davis's Straits. Previous to the revolt of the North American provinces this fishery, as well as that in the Southern Ocean, was prosecuted with great spirit by the colonists of Massachusetts. Just before the beginning of the war they employed annually 183 ships of 13,820 tons in the Northern, and 121 ships of 14,026 tons in the Southern whale fisheries.

It was not until after the breaking out of war between England and the American provinces had, for a time at least, interrupted this spirit of enterprise, that England embarked in the Southern fishery. Towards the close of the last century, the number of English vessels so employed was considerable; in 1791 they amounted to 75, but the number has since greatly fluctuated. It requires a considerable sum of money to fit out a ship. A new vessel of the size usually employed —350 tons—costs, when ready for sea and fully provisioned, from 12,000*l.* to 15,000*l.*; and the adventurer must wait three years for the return of his capital.

FISTULA LACRYMALIS. [Lacrymal Organs, Diseases of.]

FIT. [Syncope.]

FIXED AIR. [Carbonic Acid.]

FIXED OILS. The fixed oils constitute an important division of that well-known group of natural substances generically termed fatty matters. The name oil sufficiently indicates the liquid character of the members of this division; and they are said to be *fixed*, because they may be heated to nearly 500° Fahr. without undergoing material change, that degree of heat being far above the temperature necessary for the perfect volatilisation of any of the *essential oils*—another division of the fatty group. [Essential Oils.]

Source. Fixed oils are mainly obtained from the vegetable kingdom, residing for the most part in the seed, but occasionally in the fruit of plants. Certain cold-blooded animals, notably the cod-fish, and several cetaceans, such as the sperm whale, also furnish fixed oils of considerable economic value. [Oils, in Nat. Hist. Div.]

Preparation. The most usual method of obtaining a fixed oil is by submitting the substance from which it is to be extracted to strong pressure. For this purpose hydraulic presses are very generally employed. Heat is occasionally made use of to increase the liquidity of the oil, the plates of the press being kept hot for this purpose, and the substance itself usually previously exposed in bags to the action of steam. Oil obtained in this way may be rendered quite bright and transparent, either by subsidence, or filtration through paper or flannel. Another process for obtaining fixed oil consists simply in boiling the substance with water, when the oil rises to the surface and may be skimmed off. A useful laboratory method of extraction is digestion of the substance in alcohol or ether, or a mixture of the two, and subsequent separation of the solvent by heat.

Purification. But few oils are at once obtained from their natural source in a state fit for use, and no generally applicable process can be named by which they may be refined and bleached. Exposure to light in glass bottles is sufficient to decolorise many of them. Digestion with strong sulphuric acid for a time, and subsequent treatment either with cold water, or if necessary with steam, or simply blowing steam through the oil without the addition of sulphuric acid, are other methods of purification. Tannic acid, under the form of a strong decoction of oak bark, is occasionally employed to separate albuminous and gelatinous matter. Caustic soda, in small quantity, with the aid of heat, will generally separate sulphur contained in an oil, and improve its appearance and odour. Chromic acid is perhaps the most energetic oil-bleaching agent. It is conveniently applied by adding to the oil a saturated solution of bichromate of potash containing nearly half its weight of strong sulphuric acid. The *rancidity* of oils may be removed by washing with cold water alone, or with a very dilute aqueous alkaline solution.

Properties. The fixity of the bodies under consideration is obviously their great characteristic. Their specific gravity is always less than that of water, ranging from 0·90 to 0·93. Their consistence varies; heat renders them more liquid, cold congeals or solidifies them. When perfectly pure they have little or no smell, but as usually met with possess more or less characteristic odours, due to the presence of such volatile matters as butyric, valeric, or caproic acid, &c. When these matters are present in excess, oils are said to be rancid.

The fixed oils are insoluble in water, and, with the exception of castor oil, almost insoluble in alcohol; they however readily dissolve in ether, benzole, and oil of turpentine, and are miscible in all proportions with each other and with the essential oils. When heated in close vessels to 500° or 600° Fahr. they are decomposed, irritating vapours are evolved, and permanently gaseous bodies, as well as some liquid and solid substances, are produced. These products are all inflammable, burning with a luminous flame; indeed an ordinary oil-lamp is a miniature apparatus for the combustion of the products of the destructive distillation of oil. [Candle Manufacture.]

In chemical composition the fixed oils greatly resemble each other. They contain Fatty Acids, in slightly variable proportions, united with glycerin: the oleate of glycerin, however, preponderating. Ammonia acts upon fixed oils, converting them into amides; but the other caustic alkalies, and some metallic oxides, form with them true soaps. All fixed oils are more or less acted upon when exposed to the air. Some slightly thicken and acquire rancidity, but do not become solid; others rapidly absorb oxygen, give out heat, and ultimately dry up into a kind of resin. When the latter kind of oils are exposed to the air in a finely divided state, such as occurs when paper, cotton, shavings, straw, &c., are saturated with them, this oxidising action goes on at such a rate that the heat evolved is sufficient to cause the inflammation of the mass. [Combustion, *Spontaneous.*]

Drying and non-drying oils. From what has just been stated, it is evident that fixed oils may be divided into these two classes. The principal *drying oils* are those of linseed, poppy, sperm, walnut, cod-liver and hemp. They are largely used in the preparation of varnishes and by the painter as vehicles for pigments. Their drying property is considerably increased by heating them with litharge (oxide of lead) or with oxide of manganese; they are then technically termed *boiled oils.* The chief *non-drying oils* are those of almond, colza, olive, rape, as well as all that are of animal origin: they are further distinguished from the drying oils by being converted into the solid state by mercurous nitrate or by $\frac{1}{200}$th part of their weight of peroxide of nitrogen (NO_4), and are used in cookery, for lubricating machinery, and for burning in lamps.

Tests for purity. General tests for the purity of fixed oils are smell, taste, and specific gravity. Special tests for the principal of them will be found described under their respective names. The action of sulphuric acid is also a valuable aid in individualising the fixed oils; a table of the action of, and details concerning, this reagent will be found in 'Cooley's Cyclopædia of Practical Receipts,' article 'Oils.'

Another systematic method, by Calvert, is described in 'Muspratt's Chemistry' as applied to the arts and manufactures, article 'Oil.'

Alphabetical list of the chief fixed oils.

Almond oil. [Amygdalus.] A non-drying oil.

Appleseed oil. Obtained by expression from apple-pips. It resembles poppy oil.

Bay oil. Non-drying. [Laurus Nobilis in Nat. Hist. Div.]

Beech oil. Non-drying. Sp. gr. 0·9225. [Beech. Fagus in Nat. Hist. Div.]

Belladonna oil. From the fruit of *Atropa Belladonna.* Sp. gr. 0·925: a drying oil.

Ben oil. [Ben, oil of.] Non-drying.

Cacao oil. [Cacao.] Non-drying.

Camelina oil. From the seed. [Camelina Sativa in Nat. Hist. Div.] Drying. Sp. gr. 0·9252.

Carapa oil. From the fruit. [Carapa in Nat. Hist. Div.]

Castor oil. Obtained by expression from the seeds of *Ricinus Communis.* Sp. gr. 0·969. Dries by very long exposure. Its nauseous taste is said to be removed by agitation with magnesia. Is miscible with alcohol. Contains a modification of oleic acid termed *ricinoleic acid.* Heated with caustic potash, sebacic acid is produced, hydrogen is evolved, and caprylic alcohol distils over.

Cebadilla oil. From the seed. [Cebadilla in Nat. Hist. Div.]

Cherry-stone oil. From the kernel. Sp. gr. 0·9239.

Chestnut oil. From horse-chestnuts. Non-drying. Sp. gr. 0·927.

Cocoa-nut oil. Non-drying. Solid at common temperatures. [Cocos, in Nat. Hist. Div.]

Cod-liver oil. From the liver of the common cod-fish. [Morrhua *vulgaris* in Nat. Hist. Div.] To obtain a pure pale yellow oil for medicinal purposes, the livers, after washing with cold water, are submitted to gentle heat in steam-jacket pans for about three quarters of an hour; on cooling, the oil separates and floats on the surface, is skimmed off and clarified by subsidence in deep cisterns and by filtration, first through flannel, and finally through moleskin under pressure. It is exported from Newfoundland in casks, one manufacturer alone producing between 20,000 and 30,000 gallons annually.

Other cod-liver oils occur in commerce; they are all of a more or less brown colour, and are obtained from the livers after exposure to the sun. The livers undergo putrefactive fermentation, and yield a larger per centage of oil than when treated as already described for the medicinal oil. The livers of other fish than the cod are also used in the manufacture of common cod oil. It is principally used by curriers for dressing leather.

Colza oil. Non-drying. [COLZA, OIL OF.]

Cornelberry oil. Non-drying. From the fruit. [CORNUS *sanguinea*, in NAT. HIST. DIV.]

Cotton-seed oil. From the seeds of one of the cotton plants. [GOSSYPIUM *barbadense*, in NAT. HIST. DIV.] This oil dries on exposure to the air.

Cress oil. From the seeds of common garden cress (*Lepidium sativum*). Sp. gr. 0·924. Drying.

Croton oil. [CROTON OIL.]

Cucumber oil. From the seeds of several species of *Cucumis* and *cucurbita*. Drying. Used for lamps. Sp. gr. 0·9231. Known also as *Gourd oil.*

Cyper-grass oil. One of the very few oils obtained from the *root* of a plant (*Cyperus esculenta*). Non-drying. Sp. gr. 0·918.

Garden-spurge oil. [EUPHORBIA *lathyris*, in NAT. HIST. DIV.]

Gingelly oil. From the seeds of *Sesamum orientale.* Also known as *Teel oil*, *Benne oil*, and *Oil of sesamum.* It is non-drying.

Gourd oil. See *Cucumber oil.*

Grapeseed oil. By expression from the seeds of grapes. Used in salads and for burning. Sp. gr. 0·9202. Also known as *Oil of winestones.* It dries on exposure.

Ground-nut oil. Non-drying. [ARACHIS *hypogæa*, in NAT. HIST. DIV.]

Hemp oil. From the seeds of common hemp. [CANNABIS *sativa*, in NAT. HIST. DIV.] Soluble in alcohol. Sp. gr. 0·9276.

Henbane-seed oil. Non-drying. Sp. gr. 0·913. [HYOSCYAMUS, in NAT. HIST. DIV.]

Indayaçu oil, From the seeds of *Anda Gomesii.* Properties similar to those of castor oil.

Jatropha oil. [JATROPHA *curcas*, in NAT. HIST. DIV.]

Julienne oil. Drying. Sp. gr. 0·9281. From the seeds of Dame's violet. [HESPERIS *matronalis*, in NAT. HIST. DIV.]

Kundah oil. [CARAPA, in NAT. HIST. DIV.]

Lard oil. Crude oleic acid. A secondary product in the manufacture of stearin, or obtained from lard by boiling with alcohol. Sp. gr. 0·9003.

Laurel oil. See *Bay oil.*

Linseed oil. [LINSEED OIL.]

Mace oil. See *Nutmeg oil.*

Madia oil. [MADIA, in NAT. HIST. DIV.]

Mustard oil. The seeds of the white mustard (*Sinapis alba*), yield from thirty to forty per cent. of an oil used in salads. Many other species of sinapis yield a similar oil. That from black mustard is used externally as a stimulant. The seeds of wild mustard (*Raphanus raphanistrum*) also yield a fixed oil.

Neat's-foot oil. Floats on the surface of the water in which neat's feet are boiled. It is used for lubrication and for softening leather.

Nettle-tree oil. From the kernels of the *Nettle-tree* (*Celtis australis*). Used for burning.

Nickar oil. From nickar nuts, the kernels of *Guilandina bonducella.*

Nut oil. The kernels of the common hazel nuts [CORYLUS *avellana*, in NAT. HIST. DIV.] contain more than half their weight of an excellent drying oil. Sp. gr. 0·926.

Nutmeg oil. The so-called *expressed oil of mace*, is a mixture of the essential and fixed oils of the nutmeg. It is obtained on pressing the bruised nutmegs between hot plates. [MYRISTICA, in NAT. HIST. DIV.]

Olive oil. [OLIVE OIL; OLEA *europæa*, in NAT. HIST. DIV.]

Palm oil. Solid. Largely used in soap and candle manufacture. Sp. gr. 0·968. [ELÆIS, in NAT. HIST. DIV.]

Palma-Christi oil. See *Castor oil.*

Pine-nut oil. From the seeds. [PINUS *pinea*, in NAT. HIST. DIV.]

Pine top oil. From the Norway spruce fir. Dries on exposure. Sp. gr. 0·9285.

Piney oil, pœno tallow. [VATERIA, in NAT. HIST. DIV.]

Pistachio nut oil. From the kernels. [PISTACIA *vera*, in NAT. HIST. DIV.]

Plumstone oil. The kernels of the common plum (*Prunus domestica*) contain thirty per cent. of a lamp oil. Sp. gr. 0·9127. Non-drying.

Poppy oil. The seeds of the common white poppy contain half their weight of fixed oils. It dries well, and is much used in the manufacture of paints and soaps, also in salads, and to adulterate almond oil. Sp. gr. 0·9244. [PAPAVER *somniferum*, in NAT. HIST. DIV.]

Prune-stone oil. The kernels of the common prune contain an oil resembling that of almonds, but it rapidly becomes rancid. Sp. gr. 0·9127.

Radish seed oil. From the seeds of a variety of the common radish. Non-drying. Sp. gr. 0·9187.

Rape oil. From the seeds of *rape* (*Brassica compestris*). When refined by treating with sulphuric acid, it is used for common purposes in the place of olive oil.

Sabadilla oil. See *Cebadilla oil.*

Sassafras-nut oil. From the kernels. [NECTANDRA *puchury minor*, in NAT. HIST. DIV.]

Seal oil. Obtained from the blubber of several species of seal [PHOCIDÆ, in NAT. HIST. DIV.], the portion that first drains away being palest in colour and most valuable. Used for burning and leather dressing.

Sesamum oil. See *Gingelly oil.*

Shark-liver oil. From the livers of several species of *Squalidæ*. It is the lightest of all the fixed oils, having a sp. gr. of 0·866.

Skate oil. From the livers of various skates (*Raiania*). It resembles cod-liver oil.

Sperm oil. A valuable oil for lamps, and for lubricating machinery. It is the liquid portion of the fatty matter found in various parts of the White or Sperm whale (*Physeter macrocephalus*), the solid portion being spermaceti. [SPERMACETI, in NAT. HIST. DIV.]

Sunflower oil. From the seeds of the common sunflower. Used for burning, and in salads. Sp. gr. 0·9261.

Teel oil. See *Gingelly oil.*

Tobacco-seed oil. A good drying oil, obtained from the seeds of the tobacco plant (*Nicotiana tabacum*). Sp. gr. 0·9232.

Touloucouna oil. [CARAPA, in NAT. HIST. DIV.]

Train oil. See *Whale oil.*

Walnut oil. The kernels of walnuts contain half their weight of a fixed oil, sometimes used in mixing up colours for house-painting.

Weld oil. From the seed of *dyer's woad* (*Reseda luteola*). It dries on exposure. Sp. gr. 0·9358.

Whale oil. From the blubber of the common or Greenland Whale. It somewhat resembles sperm oil, but is darker in colour and of disagreeable odour. It is used as a lubricating agent, and is occasionally burnt in lamps. Sp. gr. 0·927.

Wine-stone oil. See *Grapeseed oil.*

FIXTURES. The term "fixtures" is frequently used to signify articles of a personal nature which have been affixed to land, whether removeable or not, and sometimes expressly to denote articles which are not by law removeable when once attached to the freehold: but the term "fixtures," in its correct legal sense, signifies such things of a personal nature as have been annexed to the realty, and which may be afterwards severed or removed by the party who annexed them, or his personal representatives, against the will of the owner of the freehold. When the article is not so removeable, it is to all intents and purposes part of the freehold, and subject to the rules and incidents of real property.

It is necessary, in order to constitute a fixture, that the article should be let into or united with the land, or to other substances previously connected therewith. Goods, and even buildings of the most ponderous description, do not fall under the description of fixtures, if they are merely laid and rest upon the earth without being let into it. Something more than mere juxta-position is required, as, for instance, that the soil shall have been displaced for the purpose of receiving the article, or that the chattel shall have been connected or otherwise fastened to some fabric previously attached to the ground.

The old rule of law was, that whatever was once fixed to the land was thereby made a part of it, so as to be irremoveable by any one but the owner of the fee-simple. But the strictness of this rule has been from time to time considerably relaxed, regard being had to the object of the annexation, the nature of the article, the relation of the parties between whom questions have arisen, and other considerations. Questions as to fixtures arise principally between three classes of persons. 1st, Between landlord and tenant; 2ndly, Between the executors of a tenant for life or in tail and the remainder-man or reversioner; and, 3rdly, Between the heir and the executor of the party who put up or attached the article to the premises.

1. As to the law of fixtures between landlord and tenant.

A tenant may in general remove articles which he has himself affixed to the premises solely for the purpose of trade and manufactures, wherever the removal is not contrary to any prevailing custom of trade. It cannot however be said to be established that a tenant may remove substantial and permanent additions to his premises on the ground of their having been built exclusively for the purposes of his trade, such as workshops, storehouses, mills, or other buildings of that description; nor is it clear that trade-erections of a less substantial character, such as furnaces and flues of smelting or glass-houses, or the stories and floors of malting-houses, &c., are in all cases removeable by a tenant. In such cases, somewhat will depend upon the degree in which the freehold will be deteriorated by the removal of the article, or the article itself injured or destroyed before it can be taken away.

There are also instances in which articles which have been fixed to the freehold, partly for the purposes of trade and partly for other purposes, have been held removeable. Besides the above, many fixtures slightly put up for the ornament of a house or for domestic use may also be removed by the tenant. But things attached to the freehold for agricultural purposes only are not removeable.

The following lists, given by Chitty, in his treatise on the 'Law of Contracts' (6th edit.), show what fixtures have been decided or considered, according to judicial dicta, to be removeable or not as between landlord and tenant.

1. List of things held not to be Removeable by the Tenant:—

Agricultural erections.
Alehouse bar.
Barns fixed in the ground.
Beast-house.
Benches.
Box-borders.
Carpenter's shop.
Cart-house.
Chimney-pieces (in general).
Conservatories.
Doors.
Dressers.

- Flowers.
- Foldyard walls.
- Fruit trees.
- Fuel-house.
- Glass windows.
- Hearth.
- Hedges.
- Improvements, permanent.
- Jibs.
- Keys.
- Locks.
- Millstones.
- Partitions.
- Pigeon-house.
- Pineries substantially fixed.
- Pump-house.
- Racks in stables.
- Strawberry beds.
- Trees.
- Waggon-house.
- Windows.

2. List of things held to be Removeable by the Tenant (though not Trade Fixtures):—

- Arras hangings.
- Barn set on blocks, &c.
- Beds fastened to ceiling.
- Bells.
- Bins.
- Blinds.
- Book-cases.
- Buildings set on blocks.
- Rollers, pillars, &c.
- Cabinets.
- Chimney backs.
- Chimney-glasses.
- Chimney-pieces (ornamental).
- Cider mills.
- Cisterns.
- Clock-cases.
- Coffee-mills.
- Cooling coppers.
- Coppers.
- Cornices (ornamental).
- Cupboards.
- Dutch barns.
- Furnaces.
- Furniture, fixtures put up as.
- Granary on pillars.
- Grates.
- Hangings.
- Iron backs to chimneys.
- Iron chests.
- Iron malt-mills.
- Iron ovens.
- Jacks.
- Lamps.
- Looking-glasses.
- Malt-mills.
- Marble chimney-pieces.
- Marble slabs.
- Mash-tubs.
- Mills on posts.
- Mills laid on brick foundations.
- Ornamental fixtures.
- Ovens.
- Pattens, erections on.
- Pier-glasses.
- Posts.
- Presses.
- Pumps slightly attached.
- Rails.
- Ranges.
- Sheds.
- Shelves.
- Sinks.
- Slabs of marble.
- Stable on rollers.
- Stoves.
- Tapestry.
- Tubs.
- Turret clocks.
- Vessels, &c., on brickwork.
- Wainscot, fixed by screws.
- Water-tubs.
- Windmill on posts.

3. List of Trade Fixtures decided or said to be Removeable by the Tenant:—

- Accessary buildings, that is, accessary to a removeable utensil.
- Brewing vessels and pipes.
- Cider-mills.
- Cisterns.
- Closets.
- Colliery machines.
- Coppers.
- Counters.
- Cranes.
- Desks.
- Drawers.
- Dutch barns.
- Engines.
- Fire engines.
- Fruit trees planted by nurserymen.
- Furnaces.
- Gas pipes.
- Glass fronts.
- Iron safes.
- Machinery, let into caps or steps of timber, or fixed with screws to the floor or to sockets of lead let into the stonework of the building.
- Partitions.
- Plants and pipes of brewers, distillers, &c.
- Presses.
- Pumps.
- Reservoirs.
- Salt-pans.
- Shelves.
- Shrubs planted for sale.
- Soap works, fixtures in.
- Steam-engines.
- Stills.
- Trees planted for sale.
- Varnish-house.
- Vats.

There are also certain fixtures as to which the right of removal is unsettled, but has been the subject of discussion, in determining some of the cases already referred to; of the doubtful articles the subjoined is a list:—

- Brick-kilns.
- Frames in nursery grounds.
- Furnaces in smelting-houses and glass-houses.
- Glasses in nursery-grounds.
- Green-houses.
- Hot houses.
- Lime-kilns.
- Malting-floors, stoves, &c.
- Pavements.
- Sheds.
- Storehouses.
- Tables, fixed or dormant.
- Verandahs.
- Wind or water mills.
- Workshops.

It must not however be assumed that no circumstances can except the enumerated articles from the decisions respecting them. The peculiar circumstances of each case, the state or position of the fixtures in question, and the consideration of the degree of injury to be caused by their removal, are so much regarded by the courts that few decisions can be regarded as absolute authorities for other cases, even with respect to fixtures of a similar description.

The general rule is, that a tenant must remove his fixtures before the expiration of his tenancy, or during such time as he continues in possession under a right to consider himself as tenant, for he is not at liberty to insist on his claim afterwards. And if the interest of the tenant is of uncertain character, as of a tenant strictly at will, or *pur autre vie*, it is the common opinion that he will be entitled to a reasonable time after the determination of his tenancy to remove his fixtures.

The rights both of landlord and tenant with respect to fixtures are frequently modified and controlled by the terms of the demise, according to the general principle that parties may, by entering into a special contract, vary their legal rights with respect to each other. Thus, a covenant by the tenant to keep in repair all erections and buildings erected and built, "and thereafter to be erected and built," and to surrender them at the end of the term, will preclude him from removing erections put up by himself, and which, but for the covenant, might have been legally removed as trade fixtures. And therefore a tenant, before severing an article from the freehold, must consider his right not only under the general law of fixtures, but as it may be affected by an express or implied covenant in his lease.

It should be observed, that any erection or building, whatever be its purpose, and however substantial it be in itself, unless it be affixed to the freehold according to the definition of a fixture before given, will not belong to the landlord at the end of the term. Thus, if the tenant erect a barn, granary, stable, or other building upon blocks, rollers, pillars, or the like, the landlord will not be entitled to it as part of his freehold. The tenant may therefore, by adopting appropriate modes of construction, make many valuable additions to his premises without losing his property in them, and at the same time avoid the effect of a covenant to repair erections which are put up by him during the term.

2. As to the law of fixtures between tenants for life or in tail, or their personal representatives, and the remainder-man or reversioner.

There are only few cases in which the claims of tenants for life or in tail to fixtures have come before the courts; but it appears generally from the authorities, that fixtures set up either wholly or partially for the purposes of trade form part of the personal estate of a tenant for life or in tail, and are excepted out of the general rule in favour of the inheritance; and it may be inferred from the analogy of decisions in cases between heir and executor, that the exception will extend to certain articles put up for ornament or convenience, provided they are not united to the freehold by any permanent or substantial mode of annexation.

It is necessary to distinguish between the rights of tenants for life and in tail under the law of fixtures from those which they possess under the general principles of tenure as incident to their estates. A tenant in tail, by reason of the nature of his estate, may, independently of the law of fixtures, remove any thing he has affixed to the premises. A tenant for life, again, is not in general entitled to commit any kind of waste; but if he holds his estate *without impeachment of waste*, he possesses powers arising out of his estate similar to those of the tenant in tail. [WASTE.] But in either case those powers must be exercised during the life of the tenant, as they cease at his death, and nothing survives to his representative except his right under the law of fixtures.

Ecclesiastical persons are considerered as tenants for life of their benefices, and the rights of such persons or their representatives with respect to annexations made by them to the freehold resemble very nearly those of other tenants for life.

3. As to the law of fixtures between heir and executor.

There appears to be more uncertainty in the doctrine of fixtures as between the heir and the executor, than between any other class of persons. In the early periods of the law, the rule that whatever was affixed to the freehold should descend to the heir as parcel of his inheritance, was rigidly adhered to, and even in later times the decisions and dicta of the judges upon the subject are by no means easy to reconcile. It may however be inferred from them generally, that as between the heir and executor trade fixtures and fixtures erected partly for trade and partly for other purposes, are part of the personal estate. This will be the case when the fixtures have been put up for the purposes of a trade which is merely personal, and has no connection with the land, and even in some cases, as that of Cider-mills (see 3 Atk. 14), where the trade is connected with the profits of the land; but if the property in question is absolutely essential to the value and enjoyment of the land, as was decided with respect to Salt-pans (1 H. Bl., 260, *n.*), it cannot be removed by the executor, but will descend to the heir as part of the inheritance. There are some articles put up for ornament or domestic use to which the executor has been held entitled, such as pictures, mirrors, hangings, cornices, &c., where the degree of annexation is slight, and the freehold will not be much deteriorated by the removal.

In questions with respect to fixtures, whether between landlord and tenant, tenant for life or in tail and the person entitled in remainder or reversion, or between heir and executor, much will frequently depend, not only upon the nature of the article, but also upon its construction, and the mode of its annexation to the freehold. The rule as to severance is construed most liberally in favour of the tenant as against the landlord, not quite so strongly in favour of the tenant for life or in tail, as against the remainder-man or reversioner, and in favour of the heir rather than that of the executor. This must always be remembered in drawing inferences from decisions between different parties. Thus a decision in favour of the executor against the heir may be relied on between whatever parties the question may arise, but decisions in favour of the tenant against the landlord cannot be relied upon as conclusive in cases between other parties.

With respect to the transfer of fixtures the general rule is, that a conveyance or mortgage in general terms of lands and houses includes personal chattels attached thereto, though such chattels might otherwise have been removed under the law of fixtures. When the conveyance is not general, but contains a stipulation that "the fixtures are to be taken at a valuation," the question what fixtures are included (in the absence of a schedule or specification) is to be determined by the relative situation in which the parties are placed by the conveyance. If the conveyance be an absolute sale, then those articles only should be valued which would be fixtures as between heir and executor; if there be a demise only, or the assignment of a lease, the valuation should extend to all that would be considered tenant's fixtures as between landlord and tenant. If the description of the premises in the renewal of a lease contain the general terms, "lands, buildings, erections," &c., fixtures are considered to be included in the demise, and the tenant cannot afterwards remove them, whatever were his rights before the new lease was granted.

It is now settled that contracts exclusively for the sale of fixtures are valid without the formalities prescribed by the 4th section of the Statute of Frauds (29 Car. II. c. 3); though if the slightest interest in the realty be intended to pass, the statute will apply. It would seem too, that a contract for the sale of fixtures is not within the 17th section of the statute as a contract for the sale of goods and chattels.

(See the Treatise of Messrs. Amos and Ferard on the *Law of Fixtures;* and Chitty, *On Contracts*, 6th ed.)

FLAG, the ensign or colours of a ship hoisted to denote nationality, or as a signal. The word is usually supposed to have been derived from the Anglo-Saxon *fleogan*, to fly or float in the wind; but the motion of a flag in the air being similar to the flickering of a flame, the origin of the word may probably be in the very old Latin root "flag," to flare or blaze.

The supreme flag of Great Britain is the royal standard, which is only to be hoisted when the sovereign or one of the royal family is present; the second is that of the anchor on a red field, which characterises the lord high admiral, or lords commissioners of the Admiralty; and the third is the union flag, in which the crosses of St. George, St. Andrew, and St. Patrick are blended. This flag is appropriated to the admiral of the fleet, who is the first naval officer under the lord high admiral. The British ensign is red with the union jack borne as a *canton*. The Customs department is distinguished by its having a crown in the *field* as a *bearing*.

In the British navy a fleet is divided into three squadrons—the centre, the van, and the rear; the centre being distinguished by red ensigns, the van by white, and the rear by blue, and respectively commanded by an admiral, a vice-admiral, and a rear-admiral. When the fleet is very large, there are three divisions in each squadron; and each squadron has then its admiral, vice-admiral, and rear-admiral, who respectively hold the command of its centre, van, and rear divisions. The admirals are divided in like manner, there being an admiral, a vice-admiral, and a rear-admiral of the red squadron, and so of the white and blue squadrons; but in all cases an admiral carries his flag at the main, the vice-admiral at the fore, and the rear admiral at the mizen.

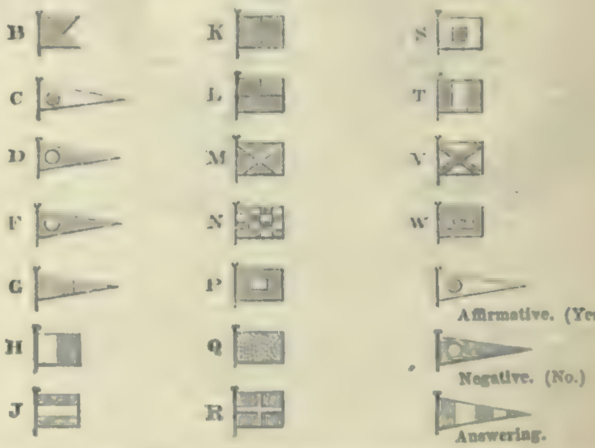
The three flags are plain red, white bearing the red cross of St. George, and plain blue; and the ensign worn by the ship that carries a flag, as well as by every ship belonging to the same squadron, is always of the same colour as that of the flag-officer commanding it. Various kinds of flags are used in addition, to convey orders, to ask assistance, to announce arrivals, &c.; and a regular system of communication can be readily maintained between fleets or ships at sea.

In the British merchant service, which contains nearly 40,000 registered vessels, increasing in number about 1500 in new vessels annually, the want of a more simple communication by signal became so pressing that in 1855 a committee was appointed by the Board of Trade to consider the subject. Marryatt's excellent code had been used for nearly half a century, and, from the difficulty which affects all radical changes in public systems, years will pass before it is wholly discontinued. It has, however, been determined by the committee that signals for the merchant service ought to extend to at least 70,000 or 80,000 in number; and that no signal should have more than 4 flags in a hoist. Steamers have in general much shorter masts than sailing vessels, and therefore the higher numbers of Marryatt's Code requiring 5 flags, has been pronounced a solid objection thereto.

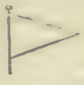
After considerable attention to the subject by the committee, composed of highly competent members, it has been resolved that a new system containing 18 flags and 3 pendants, which would furnish 78,642 signals, each consisting of not more than 4 flags in a hoist, be adopted in the merchant navy of Great Britain. This so desirable a change, effected by the substitution of *letters* for numbers (omitting the vowels) gives to the merchant marine, not only a comprehensive and simple code capable of extension, but furnishes an authorised base on which to found an *Universal System*, which other nations will doubtless approve and apply.

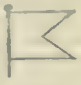
From the rapidly increasing interest which attaches to nautical matters in this country, we subjoin a list of flags under this new system:—

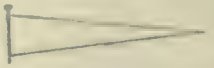
N.B. Blue is represented by lines, thus ▤
Red " " ▥
White " absence of all lines
Yellow " lines, thus ▨

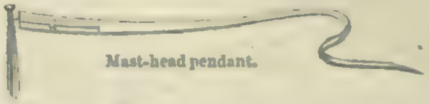


The following are the names of the varieties of flags in the sea service, the ordinary square flag being the one most in use. It has of late years become a custom for shipowners each to adopt a private, or as it is called, a "House Flag."


Burgee.


Cornet.


Signal pendant.


Mast-head pendant.

FLAGELLANTS, FLAGELLATION. The idea of propitiating the Deity by self-torment dates from a remote antiquity. Herodotus relates (ii. 42) that the Egyptians flogged themselves at one of their annual celebrations. Flagellation was administered as a trial of fortitude to the young Lacedæmonians, who it seems, in accordance with the peculiar institutions of Lycurgus, did not attach to this castigation the idea of degradation which modern Europeans do. In Rome, however, the punishment of flagellation was only applied to slaves, and it seems to have been pretty common, as different classes of slaves derived their names from the kind of whips with which they were lashed. Some were called *Restiones*, because they were lashed only with cords; others *Buccdæ*, from being flogged with thongs of ox-leather. It is in reference to this custom that Plautus makes one of his personages say—"*Erunt Buccdæ inviti potius quam ego sim Restio.*" "They shall be Buccdæ whether they will or no, before I be Restio." The Jews employed flagellation as a punishment, but never as a voluntary act of devotional exercise. This practice was unknown to the primitive Christians; neither does it appear that the first hermits of the Thebaid added self-flagellation to the different modes of penance with which they tortured their body. The rules of the first monasteries in the East, drawn up by St. Anthony, Paphnutius, Macarius, and others, contain no ordinance as to that kind of discipline, neither is it mentioned in the original regulations of the Benedictine order, the first that was established in the West. The legends which describe the lives of the saints who lived before the beginning of the 5th century never speak of self-flagellation amongst the various torments which the above-mentioned saints inflicted on themselves.

The first known instances of this kind of self-mortification occur about A.D. 400, and from that time they became continually more frequent till the year 1056, when Cardinal Peter Damian de Honestis promoted by all his influence the practice of self-flagellation, which the learned author of the 'Ecclesiastical Annals,' Cardinal Baronius, calls "a laudable usage of the faithful." Damian's efforts were attended with great success, and the chroniclers relate that persons of religious dispositions were seen everywhere armed with whips, thongs, and rods, lacerating their own skins in order to draw down on themselves the blessings of Heaven. This practice began to spread so widely that many of the less bigoted clergymen endeavoured to discountenance it, but unsuccessfully, and it became every day more prevalent among the besotted crowds of that dark age. About the year 1260 the intoxication was complete. People being no longer satisfied to practise similar mortifications in private, began to perform them in public on pretence of greater humiliation. Regular associations and fraternities were formed for that purpose; and the extravagancies which they committed were of such a nature that even the contemporary writers, although accustomed to such scenes, seem to have been struck with astonishment. The monk of St. Justina, the first author who gives a circumstantial account of these fanatics, says the practice was attended with good effects.

"Then," continues the same author, "those who were at enmity with one another became friends. Usurers and robbers hastened to restore their ill-gotten riches to their right owners. Others who were contaminated with different crimes confessed them with humility, and renounced their vanities. Jails were opened, prisoners were set free, and banished persons permitted to return to their native habitations."

This sudden repentance was the effect of the terror inspired by the general belief that the end of the world was at hand. Such mental fever could not last very long, and indeed it seems to have soon subsided. But in the 14th century, when the imaginations of the people were excited by the terrible pestilence known under the appellation of the black death, which desolated all Europe during that century, the flagellation mania broke out with new fury. The flagellants held that flagellation was of equal virtue with baptism, that the law of Christ was about to be abolished, and a new law, enjoining the baptism of blood, to be administered by whipping, was to be substituted in its place. Not only all the scenes of the 13th century were re-enacted, but the excesses of fanaticism became even worse than before. The flagellants spread over all Europe, and a band of them reached London in the reign of Edward III. Their number consisted of 120 men and women. Each day at an appointed hour they assembled, ranged themselves in two lines, and paraded the streets scourging their naked shoulders and chanting a hymn. At a given signal, all with the exception of the last, threw themselves flat on the ground; and he who was last, as he passed by his companions, gave each a lash, and then also lay down. The others followed in succession till every individual in his turn had received a stroke from the whole brotherhood. The citizens of London gazed and marvelled, pitied and commended; but they went no farther. Their faith was too weak, or their skins too delicate; and they allowed the strangers to monopolise all the merits of such a religious exercise. The missionaries did not make a single convert, and were obliged to return without any other success than the conviction of having done their duty to an unbelieving generation. (Stow's 'Annals.')

Early in the 15th century they re-appeared in Germany, and their leader, Conrad Schmidt, was burnt as a heretic in 1414; but the sect continued to exist nearly throughout the century. Their doctrines, however, were widely different from those of their predecessors. They taught that the Roman Catholic belief in the efficacy of the sacrament, purgatory, and prayers for the dead were false; and that faith and flagellation, with a belief in the apostle's creed, were alone necessary for salvation.

The purity of the first flagellants was not long preserved by their followers, and it was but natural that a fanatical rabble, who thought that self-torment was a sufficient atonement for all possible sins, should fall into great excesses. The flagellants were soon accused of many crimes; the celebrated Gerson attacked them in his writings, and Pope Clement VII. declared them heretics, and thundered out anathemas against them. The flagellants were persecuted everywhere, and many of them were burnt as heretics. It was, however, with great difficulty that this sect was completely extirpated. For further particulars about the flagellants see all the ecclesiastical histories; and also Jacques Boileau, 'Histoire des Flagellans;' an English paraphrase of the same work appeared under the title 'Memorials of Human Superstition by one who is not a Doctor of the Sorbonne;' see also Muratori's 'Antiquit. Ital. Medii Ævi,' and Mosheim's 'Ecclesiastical History.'

FLA'GEOLET, a small pipe, or musical instrument, of the flute kind, played on by means of a mouthpiece, in the manner of the old English flute and pitch-pipe. Its compass is two octaves, from F, the first space in the treble cleff, to F in altissimo. The scale of the *quadrille flageolet* is rather more limited; and that of the *patent octave flageolet* is an octave higher than the ordinary instruments.

The *double flageolet* consists of two instruments, united by one mouthpiece, producing, as its name indicates, double notes. The use of the flageolet is now almost entirely confined to the ball-room; it is superseded by the octave flute, or *flauto piccolo*. [Flute.]

FLAKE WHITE. [Colouring Matters.]

FLAMBOYANT, a term employed by many writers to designate that style of French Gothic architecture which corresponds in time to what is commonly called the Perpendicular style in England. The name was given to it from the waving or flame-like curves of the tracery of the windows, &c. [Gothic Architecture.]

FLAME is the combustion of gaseous or of volatilised fluid or solid matter. It is attended with great heat, and sometimes with the evolution of much light; but the temperature may be intense when the light is feeble: this is the case with the flame of hydrogen gas, it being scarcely visible by daylight, though its heat is intense; the combustion of hydrogen is then an example of flame resulting from the chemical action between it and the oxygen of the air. As there is no solid matter in the flame of this gas, the light which it yields is inconsiderable; but it is greatly increased by dusting finely divided charcoal into the flame.

In the burning of a candle, the wax or tallow being first rendered fluid by heat, rises in the wick, and although the wick supplies some hydrogen and carbon, by far the greater portion of these is yielded by the wax or tallow, which burn by the assistance of the oxygen of the air. The supply of hot vapour diminishes as it ascends, and eventually fails, and hence the flame of a candle gradually tapers to a point and then ceases.

Two opinions have been entertained as to the mode in which flame is produced and propagated. According to Sir H. Davy, the flame of combustible bodies "must be considered as the combustion of an explosive mixture of inflammable gas or vapour and air; for it cannot be regarded as a mere combustion at the surface of contact of the inflammable matter; and the fact is proved by holding a taper or a piece of burning phosphorus within a large flame made by the combustion of alcohol; the flame of the candle or of the phosphorus will appear in the centre of the other flame, proving that there is oxygen even in its interior part." ('On the Safety-Lamp,' p. 45.)

In the opinion of Mr. Sym ('Annals of Phil.,' vol. viii. p. 321), "the internal part of the flame is comparatively cool, the actual combustion being diffused over the surface, and concentrated at the apex." Mr. Sym adduces many curious and important experiments in proof of his opinion; but the most decisive facts in its favour are those related by Mr. Davies ('Ann. Phil.,' vol. x., p. 447), and they appear fully to warrant the inference he has deduced from them, that the interior of flame will not support combustion, and that on account of its containing little or no oxygen.

A piece of phosphorus was placed upon a small wooden stand in a Wedgwood dish; spirit of wine was then poured into the dish in such a manner that it did not reach the phosphorus. The spirit of wine was lighted, and its flame completely enveloped the combustible body. In the course of a few seconds the phosphorus became fluid, and remained in that state upon the stand, and never in a single instance inflamed, until the alcohol was consumed or its flame extinguished, though in several instances the spirit of wine continued to burn for three or four minutes. The phosphorus always burst into a vigorous flame when the spirit of wine was extinguished. When the flame of the spirit of wine was blown upon, so that the edge of it came in contact with the phosphorus, the phosphorus immediately burst into a flame; but the flame was instantly extinguished and the boiling resumed, as soon as the flame of the alcohol was restored to its natural position.

Mr. Davies states also that a lighted wax taper surrounded by alcohol was extinguished when the alcohol was inflamed.

That flame is merely a thin film of white hot vapour, and that its combustion is entirely superficial, while inflammable matter is contained within which cannot burn for want of oxygen, is proved by inserting one end of a small hollow glass tube into the dark central portion of the flame of a large candle or of a gas-light; the interior unburnt vapour or gas will escape through it, and may be lighted at the other end of the tube.

A most intense light, employed by Lieutenant Drummond in geodetical operations, is produced by passing a stream of oxygen gas directed through the flame of alcohol upon lime turned into the form of small balls. He found the light emitted by the lime when exposed to this intense heat to be 83 times the intensity of the brightest part of the flame of an argand burner of the best construction and supplied with the finest oil. Lime has since been used with the oxy-hydrogen blowpipe for the illumination of the solar microscope.

The brilliancy of flame is much diminished by various cooling processes: thus, when a piece of glass is put over or into the flame of a candle, it becomes covered with charcoal in the state of soot, which the diminished heat of the flame is incapable of burning. This takes place to a much greater extent with oil and tallow than with alcohol; the latter containing less carbon and more hydrogen than the former, its carbon is not so readily deposited by cooling.

It is on the cooling power of the metals with regard to flame, and especially of wire-gauze, that the construction of the safety-lamp depends. [Safety-Lamp.] The uses to which flame is applied are numerous and highly important; it is employed for the purpose of giving heat in reverberatory furnaces and in the blowpipe, and for that of yielding light in gas- and oil-lamps and candles. It is to be observed, that flame is produced by various other chemical processes, and by other means than the combustion of substances containing hydrogen and carbon, though the latter are the elements from which it is obtained for all the numerous purposes of common life and manufactures.

FLAMEN, FLAMINES, one of the orders of priesthood in ancient Rome, like the Salii, the Feciales, and others, instituted, according to tradition, by Numa Pompilius. The Flamines were each destined to the service of some particular deity; there was the Flamen Dialis who was consecrated to the worship of Jupiter, and was the first in rank, the Flamen Martialis, who attended to the worship of Mars, Flamen Quirinalis, &c. They enjoyed great consideration, and their wives, called Flaminicæ, attended the sacrifices and other sacred ceremonies. But with their privileges they were subjected to great restrictions; they could not be absent from the city more than a single night; nor from their own beds more than two nights consecutively; nor mount on horseback; nor touch a horse, a dog, or a corpse; nor swear an oath; nor wear a ring with stones, &c.; and if his wife died the Flamen was compelled to resign his office. The Flamines were distinguished by a peculiar pileus, or hat, of a conical shape, which was fastened under the chin. Their number, which was originally only three, was increased afterwards as new gods were introduced, and at last even the emperors, being deified after death, had a Flamen appointed for them. The Flamines were chosen, the three named above from among the patricians, the others from the plebeians.

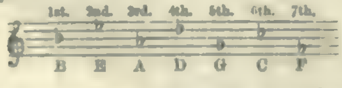
FLANK of a bastion, &c., is the term applied in fortification to that portion of a work, the fire from which being in the direction of, and in front of, any work, would take in flank the attacking party, thereby most materially aiding in the defence, for it is evident that without such works to sweep by their fire along the foot of a high revetment-wall, or parapet, the attacking party would, when they reached such a position, be safe from the besieged, except in so far as hand-grenades and shells rolled over the parapet could reach them and might place their scaling ladders, or carry on mining operations to break the ramparts, in perfect security. In fact, such has been done in Indian forts, where from the curvature or irregularity of the wall, the fire from the adjacent flanking towers was ineffective. The line of defence, or length of line flanked by a work, will depend on the range, &c., of the weapons used; with the old musket it was considered that 180 yards was the greatest length admissible. [BASTION.]

FLANNEL MANUFACTURE. Flannel is made of worsted yarn, spun much more loosely than that for most kinds of garment cloths, and finished with a less amount of dressing; but the manufacturing operations are nearly the same in principle: and therefore it will suffice to refer to WOOLLEN AND WORSTED MANUFACTURE for an account of the machinery and processes employed. It may be well, however, in this place, to mention a few specialities in relation to this branch of industry. Wales is the country in which flannel was originally made; and the flannel produced there is still held in high repute for inner vests and other purposes. This superior flannel is made chiefly about the neighbourhood of Welchpool and Newtown; it is better than most of the English, but not so cheap. The finest is made from the fleece of the Welch mountain sheep. Lancashire, and especially Rochdale and its neighbourhood, is the district where flannels are made more extensively than in any other part of the British dominions, perhaps than in any in the world. They are woven in that county in a great variety of width and substance; such as the thin gauze, the medium, the thick, the double-raised, and the swanskin flannels; some for home consumption, some chiefly for foreign. Machinery is more generally used here than elsewhere in the manufacture; that is, the mule for spinning, and the power-loom for weaving. Saddleworth, and the adjacent district of West Yorkshire, are remarkable for the manufacture of very fine flannels, which find a ready sale at good prices in London. A few cheap and common flannels are made in the Leeds district, retaining the natural colour of the wool. In the West of England, white and dyed flannels are made in small quantity, partaking somewhat of the quality of light cloth. Ireland produces coarse flannels, called *Galways*, made of Irish-grown wool, and adapted for the native population. Of continental nations, France and Belgium produce the best flannels; the fine light flannels of the first-named country are well adapted for dyeing or printing.

The extent of the exportation of flannels cannot be ascertained from the Board of Trade returns, seeing that they are combined as one among several items belonging to the class of Worsted Goods.

FLASK. In chemistry, a glass vessel of a more or less globular form, with a neck, used for heating liquids.

FLAT, in music, a character originally represented by a small *b*, though time has somewhat altered its outline, and the following is now its form—♭. The Flat is used to lower, or depress, by the degree of a semitone, any note in the natural scale. In ancient music, before the character of the Natural was introduced, the Flat was employed to reduce any note which had been made sharp, to its natural state. Where Flats are placed at the clef, they are always taken in the following order:—



When a Flat, not appearing at the clef, occurs in any other part of the composition, it only affects the bar in which it is placed, and is called an *Accidental Flat.*

The DOUBLE FLAT ( ) is frequently employed in very chromatic music. It lowers a note two semitones below its natural state. Thus, B *double-flat* ( ) is, in fact, A *natural*, &c. This character is used chiefly in Enharmonic modulation [ENHARMONIC], in which it is practically convenient, if not absolutely necessary, occasionally to have an additional name for each note in the diatonic and chromatic scales.

FLAVIN. [UREA, *Diphenyl-urea.*]

FLAVINDIN. [INDIGO.]

FLAX (*Linum usitatissimum*) is an annual plant, cultivated from time immemorial for its textile fibres, which are spun into thread and woven into linen cloth. It has a green stem from a foot and a half to two feet high, and a blue flower, which is succeeded by a capsule containing ten flat oblong seeds of a brown colour, from which an oil is expressed, which is extensively used in manufactures and in painting. There are several varieties of flax cultivated; the best seed comes from Riga and from Holland. As the different varieties arrive at maturity at different times, and the stem rises to different heights, it is very essential that the seed be not mixed, as this would occasion great inconvenience and loss in the pulling of the flax. There is a very fine long variety which is cultivated in the neighbourhood of Courtray, in Flanders; it requires a very good soil to grow in, and the stem is so long and slender that if it were not supported the least wind would break it and lay it flat, in which case the quality of the flax would be much impaired and the quantity reduced. To prevent this, short stakes are driven into the ground in a line at eight or ten feet from each other, and long slender rods are tied to them with oziers about a foot or eighteen inches from the ground, forming a slight railing to support the flax: a number of these are placed in the same manner at a short distance from each other in parallel lines all over the field, and the flax is thus prevented from being beat down. A better method, which is not commonly adopted, is to have stakes in regular rows, and thin ropes tied to them instead of rods: by having these lengthways and others across them at right angles, a kind of large net is spread over the whole field, and none of the flax can possibly be laid flat. By using cheap rope or strong tar twine from old cables, the expense is not very great, and much less room is taken up than by the rods. When the flax is pulled, the stakes are taken up, and removed to a dry place till they are wanted again.

The most common variety of flax is of a moderate length with a stronger stem: if it is not sown very thick it will throw out branches at top and produce much seed: it is therefore a matter of calculation whether it will be most profitable to have finer flax with less seed, or an inferior quality with an abundance of seed.

There is a small variety which does not rise above a foot, grows fast, and ripens its seed sooner. When linseed is the principal object, this variety is preferred; but the flax is shorter and also coarser.

Another variety of flax has a perennial root, and shoots out stems to a considerable height. It came originally from Siberia, and was much recommended at one time, but its cultivation did not spread. If it were sown in wide rows and kept free from weeds by hoeing, it might perhaps be profitably cultivated for the seed; and if the flax is inferior in quality, it might still be of some value for coarse manufactures; it requires however to be renewed every three or four years and sown in fresh ground.

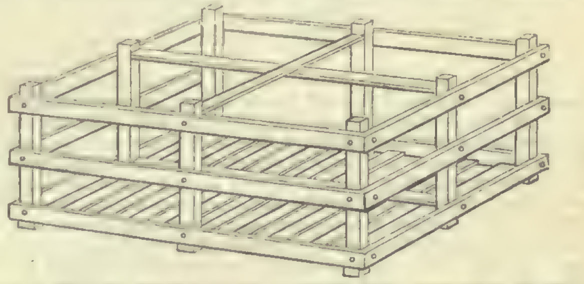
The soil best adapted to the growth of flax is a deep rich loam in which there is much vegetable mould. It should be mellow and loose to a considerable depth, with a sound bottom, neither too dry nor too moist; either extreme infallibly destroys the flax; it is therefore not suited either to hot gravelly soils or cold wet clays, but any other soil may be so tilled and prepared as to produce good flax. It thrives well in the rich alluvial land of Zealand and the polders, but it is also raised with great success in the light sands of Flanders, but much more careful tillage and manuring are required. The land on which flax is sown must be very free from weeds, the weeding of this crop being a very important part of the expense of cultivation. These circumstances suggest the best mode of preparing the land. A long fallow, such as is sometimes given to the land in Essex, including two winters and a summer, may be a good preparation on the heavier loams, which should be trench ploughed and worked deep; the manure should be dung fully rotten, or a compost of earth and dung; it should be put on the land in autumn, and well incorporated before the seed is sown. If the land is sufficiently clean, a crop of potatoes well manured may be substituted with advantage for the fallow; but at least double the usual quantity of dung should be given to this crop that enough may remain in the ground for the flax. Lime may be used if the soil contains a great portion of clay; but in the lighter loams there is some doubt of its advantage for flax. At all events it should not be used immediately before the flax is sown, but for some previous crop. Peat-ashes are excellent; they improve the soil and keep off insects, which are apt to injure the roots of the flax. For want of peat-ashes, those made by the burning of weeds and earth in a smothered fire are a good substitute. But the most effective manure is the sweepings of the streets in towns mixed with the emptying of privies and the cleaning out of the butchers' stalls and shambles. On light soils much manure is required; and where night soil cannot be obtained in sufficient quantities, rape cakes, from which the oil has been expressed, dissolved in cows' urine, form the best manure. In many parts of Flanders 500 rape cakes are used for every acre of flax, besides the usual quantity of Dutch ashes and of liquid manure, which is the drainings of dunghills and the urine of cattle collected in a cistern and allowed to become putrid.

In southern climates flax is sown before winter, because too great heat would destroy it. It is then pulled before the heat of summer. In northern climates the frost, and especially the alternations of frost and thaw in the early part of spring, would cause the flax to perish; it is consequently sown as early in spring as may be, so as to avoid the effect of hard frost. This is in April in Great Britain and Ireland, and in Holland and Flanders. In no country is the ground better prepared for the growth of flax than in Flanders; and it may therefore be interesting to follow the whole process of Flemish cultivation for several crops preparatory to that of flax, which is the most important produce in that country, and that which, when well managed, gives the greatest profit to the farmer. The best flax grows near Courtray. The soil is a good deep loam, rather light than heavy. It is not naturally so rich as the soil of the polders in Flanders and in Zealand, but the tillage and cultivation are far more perfect, and the produce, if not more abundant, is of a finer quality. Every preceding crop has a reference to the flax, and is so cultivated as to improve the texture of the soil, which is abundantly manured in order to leave a considerable surplus in the ground. If the land has not been trenched all over with the spade to the depth of eighteen or twenty inches, it has been equally well stirred by the narrow open drains which are dug out twelve or fifteen inches deep every year between the stitches in which it is laid by the plough. These drains, or water furrows, are a foot wide, and from a foot to eighteen inches deep. The earth taken out of them is spread evenly over the land after the corn is sown. When the ground is ploughed again, care is taken that the place of these water-furrows shall be shifted a foot on each side. Thus in six years the whole soil is deepened and thoroughly mixed with whatever manure has been put on. This produces the same effect as trenching, and even more perfectly. The whole of the land in which the best flax grows has been so treated for several generations, and may be looked upon as a species of compost eighteen inches deep. Potatoes or colza are usually planted with a double portion of manure, after which wheat is sown, slightly manured; then rye with turnips sown the same year after the rye. These are taken up in September or October, and stored for winter use. The land has been well weeded while the turnips were growing, and all the manure is decomposed and mixed with the soil. It is ploughed in stitches before winter, some manure having been previously spread over it if necessary; and it is left exposed to the mellowing effects of frost and snow. As soon as the winter is over, and the snow is melted, the final preparation goes on. Deep ploughing and harrowing further divide and pulverise it: the surface is laid as level and smooth as possible; and if there is no fear of too much wet, which in this light loam soon disappears, the whole is laid flat and level as a bowling-green, or else divided into beds with water-furrows between them. On this the liquid manure is poured out, and the Dutch ashes spread if any are used, or the rape-cakes, as mentioned before. The harrows are drawn over the land, and it is left so a few days that the manure may sink in. It is then again harrowed and the linseed is sown broadcast by hand, very thick and even, about one hundredweight and a half to the acre. A bush-harrow or a hurdle is drawn over, merely to cover the seed, which would not vegetate if it were buried half an inch deep. According to the state of the land it is rolled or not, or the seed is trodden in by men, as is done with fine seeds in gardens. This is only in the lightest soils. Most commonly the traineau is drawn over the land. This is a wooden frame with boards nailed closely over it, which is drawn flat over the ground to level and gently press it. In a short time the plants of flax come up thick and evenly, and with them also some weeds. As soon as the flax is a few inches high the weeds are carefully taken out by women and children, who do this work on their hands and knees, both to see the weeds better and not to hurt the flax with their feet. They tie coarse pieces of cloth round their knees, and creep on with their face to the wind, if possible. This is done that the tender flax, which has been bent down by creeping over it, may be assisted by the wind in rising. This shows what minute circumstances are attended to by this industrious people. The weeding is repeated till the flax is too high to allow of it.

The seed which is used is generally obtained from Riga, it being found that the flax raised from home-grown seed is inferior after the first year. But many intelligent men maintain that if a piece of ground were sown thin with linseed, so that the flax could rise with a strong stem, and branch out, and if the seed were allowed to ripen, the Flemish seed would be as good as that from Riga; but it still remains to be proved whether it would be cheaper to raise it or to import it.

When the flax begins to get yellow at the bottom of the stem it is time to pull it, if very fine flax is desired, such as is made into thread for lace or fine cambric; but then the seed will be of little or no value. It is therefore generally left standing until the capsules which contain the seed are fully grown and the seed formed. Every flax-grower judges for himself what is most profitable on the whole. The pulling then begins, which is done carefully by small handsful at a time. These are laid upon the ground to dry, two and two obliquely across each other. Fine weather is essential to this part of the operation. Soon after this they are collected in larger bundles and placed with the root end on the ground, the bundles being slightly tied near the seed end; the other end is spread out that the air may have access, and the rain may not damage the flax. When sufficiently dry they are tied more firmly in the middle, and stacked in long narrow stacks on the ground. These stacks are built as wide as the bundles are long, and about eight or nine feet high. The length depends on the crop; they are seldom made above twenty or thirty feet long. If the field is extensive, several of these stacks are formed at regular distances; they are carefully thatched at top, and the ends, which are quite perpendicular, are kept up by means of two strong poles driven perpendicularly into the ground. These stacks look from a distance like short mud walls, such as are seen in Devonshire. This is the method adopted by those who defer the steeping till another season. Some carry the flax as soon as it is dry under a shed, and take off the capsules with the seed by *rippling*, which is drawing the flax through an iron comb fixed in a block of wood; the capsules which are too large to pass between the teeth of the comb are thus broken off and fall into a basket or on a cloth below. Sometimes, if the capsules are brittle, the seed is beaten out by means of a flat wooden bat like a small cricket-bat. The bundles are held by the root end, and the other end is laid on a board and turned round with the left hand, while the right hand with the bat breaks the capsules, and the linseed falls on a cloth below. The flax is then immediately steeped; but the most experienced flax-steepers defer this operation till the next season. In this case it is put in barns, and the seed is beat out at leisure in winter. When flax is housed, care must be taken that it be thoroughly dry; and if the seed is left on, which is an advantage to it, mice must be guarded against, for they are very fond of linseed, and would soon take away a good share of the profits by their depredations.

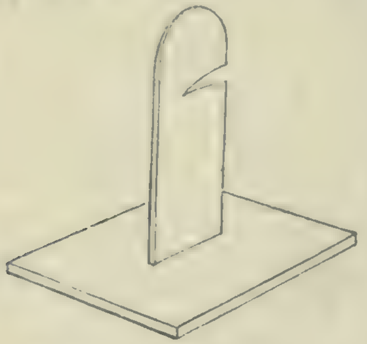
Steeping the flax is a very important process, which requires experience and skill to do it properly. The quality and colour of the flax depend much on the mode of steeping; and the strength of the fibre may be injured by an injudicious mode of performing this operation. The object of steeping is to separate the bark from the woody part of the stem, by dissolving a glutinous matter which causes it to adhere, and also destroying some minute vessels which are interwoven with the longitudinal fibres, and keep them together in a kind of web. A certain fermentation or incipient putrefaction is excited by the steeping, which must be carefully watched, and stopped at the right time. The usual mode of steeping is to place the bundles of flax horizontally in shallow pools or ditches of stagnant water, keeping them under water by means of poles or boards with stones or weights laid upon them. Water nearly putrid was supposed the most efficacious, and the mud was often laid over the flax to accelerate the decomposition: but this has been found to stain the flax, so that it was very difficult to bleach it or the linen made from it afterwards. The method adopted by the steepers of Courtray, where steeping flax is a distinct trade, is different. The bundles of flax are placed alternately with the seed end of the one to the root end of the other, the latter projecting a few inches: as many of these are tied together near both ends as form a thick bundle about a foot in diameter. A frame made of oak-rails nailed to strong upright pieces in the form of a box 10 feet square and 4 deep, is filled with these bundles set upright and closely packed. The whole is then immersed in the river, boards loaded with stones being placed upon the flax till the whole is sunk a little under the surface of the water. The bottom does not reach the ground, so that the water flows over and under it. There are posts driven in the river to keep the box in its place, and each steeper has a certain portion of the bank which is a valuable property. The flax takes somewhat longer time in steeping in this manner than it does in stagnant and putrid water, and it is asserted by those who adhere to the old method that the flax loses more weight; but the colour is so much finer that flax is sent to be steeped in the Lys from every part of Flanders. When it is supposed that the flax is nearly steeped sufficiently, which depends on the temperature of the air, the flax being sooner steeped in warm weather than in cold, it is examined carefully every day, and towards the latter part of the time several times in the day, in order to ascertain whether the fibres readily separate from the wood the whole length of the stem. As soon as this is the case the flax is taken out of the water: even a few hours more or less steeping than is necessary will make a difference in the value of the flax. If it is not steeped enough, it will not be easily scutched, and the wood will adhere to it. If it has been too long in the water, its strength is diminished, and more of it breaks into tow. The bundles are now untied, and the flax is spread evenly in rows



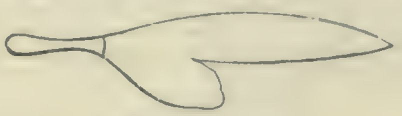
Frame in which the flax is packed to be steeped in the river Lys in Flanders.

slightly overlapping each other on a piece of clean smooth grass which has been mown or fed off close. Fine weather is essential to this part of the process, as rain would now much injure the flax. It is occasionally turned over, which is done dexterously by pushing a long slender rod under the rows and taking up the flax near the end which overlaps the next row and turning it quite over. Thus, when it is all turned, it overlaps as before, but in the contrary direction. It remains spread out upon the grass for a fortnight, more or less according to the season, till the woody part becomes brittle and some of the finest fibres separate from it of their own accord. It is then taken up, and as soon as it is quite dry it is tied up again in bundles, and carried into the barn to be broken and heckled at leisure during the winter.

In the domestic manufacture the flax is broken or scutched at home, when the weather prevents out-door work. The common break consists of four wooden swords fixed in a frame, and another frame with three swords which fit in the interstices of the first by means of a joint at one end. The flax is taken in the left hand and placed between the two frames, and the upper frame is pushed down briskly upon it. It breaks the flax in four places, and by moving the left hand and rapidly repeating the strokes with the right the whole handful is soon broken. It is then scutched by means of a board set upright in a block of wood so as to stand steady, in which is a horizontal slit about three feet from the ground, the edge of which is thin. The broken flax held in handsful in the left hand is inserted in this slit, so as to project to the right, and a flat wooden sword of a peculiar shape is held in the right hand; with this the flax is repeatedly struck close to the upright board, while the part which lies in the slit is continually changed by a motion of the left hand. This operation beats off all the pieces of the wood which still adhere to the fibre, without breaking it, and after a short time the flax is cleared of it and fit to be heckled. But the operations of breaking and scutching are tedious and laborious when thus executed by hand. A mill is now used (where large quantities of flax are required for manufactures), having three fluted cylinders, one of which is made to revolve by horse or water power and carries the other two round. The flax plants are passed between these cylinders while thus revolving, and the stalk, or *boon*, as it is technically called, is by this means completely broken without injuring the fibres. The scutching is accomplished in the same mill by means of four arms projecting from a horizontal axle, arranged so as to strike the boon in a slanting direction until the bark and other useless parts of the plant are beaten away. In the last process by which flax is prepared for the spinner, the *heckling*, the instrument employed, called the heckle, is a square piece of wood studded with rows of iron teeth about four inches long, and disposed in a quincunx order. The fineness of the heckle is chosen with reference to the quality of the flax, and heckles differing in this respect from each other are used at different stages of the dressing, the coarsest first, and the finest to give the last degree of smoothness and finish to the flax. The operation of heckling is performed by the workman grasping a handful of flax by the middle and drawing first one side or end and then the other through the teeth of the heckle until every particle of extraneous matter is removed, and the whole of the filaments are arranged in distinct, even, and parallel fibres.



Upright board to clear the flax of the wood.



Flat sword or scutcher.

The cultivation of flax in this country, notwithstanding the energetic advocacy of enthusiastic men, and even of societies established for the purpose, has been if anything declining. Mr. Warner, of Trimmingham, near North Walsham, in Norfolk, advocated the cultivation of the crop with great energy for several years, and induced many to attempt it: and in Ireland a society for the encouragement of its cultivation was supported by a government donation, and employed Belgian and other teachers to explain in the different localities the best method of cultivation. The system of steeping for weeks in order to effect the separation of the fibre, is now very generally displaced in this country by Schenk's method of soaking for a day or two in vats of warm water; and wherever manufactories on that plan have been established, and a market thus provided for the straw, the crop retains its place in our rotations. Grown after clover or almost any green crop, with diligent and cleanly tillage and liberal manuring, a crop of sufficient bulk is obtained to repay cultivation, but the peculiar and laborious character of its cultivation generally so far interferes with the ordinary economy of labour on our small farms, that it is not a general or increasing favourite with the British farmer.

FLÈCHE, a small work consisting of two faces, which form a salient angle. It is constructed at the foot or beyond the glacis of a place in order to give an advanced musquetry fire, when such is desirable from the conformation of the ground, to see down a small ravine or hollow for instance, or to enfilade a besieger's trenches.

FLETA is a commentary in Latin on the entire body of the English law, as it stood at the time when the author wrote. It is supposed to have been written about the thirteenth year of the reign of Edward I., as the statutes passed towards the end of his reign are not noticed, while that of Westminster II. is often quoted. The author gives as the reason for the title of his book, that it was written during his confinement in the Fleet Prison: who he was is not known. The author has followed Bracton in the matter and manner of his work, having adopted his plan, and in many instances transcribed whole pages from him. He also followed Glanville in many instances. Various obscure passages of both those writers are illustrated by Fleta. (Reeve's 'Eng. Law.')

The work was originally published by Selden from an ancient manuscript in the Cottonian Library, together with a small treatise in law French, entitled 'Fet Assavoir,' which is a collection of notes concerning proceedings in actions, and a learned dissertation by Selden himself. Two editions only have been published in England, one in 1647, the other in 1685, which last corrects many hundred errors which had been caused in the first edition by an unskilful copyist (Bridgman). It is also printed in Houard's collection. [BRITTON, in BIOG. DIV.] President Henault, in his 'Chronological Abridgment of the History of France,' tome i. p. 258, refers to Fleta as an historical authority.

FLEET PRISON, a metropolitan prison, pulled down in 1845, and so called from its being situated by the side of the river Fleet, now covered over. It was the prison to which persons were committed by the ecclesiastical courts, the courts of equity, and the Exchequer and Common Pleas; but was abolished by the 5 & 6 Vict. c. 22, which established the Queen's Prison (formerly the Queen's Bench Prison) as the only prison for debtors, bankrupts, and other persons who might formerly have been imprisoned in the Queen's Bench, the Fleet, or the Marshalsea prison.

FLEUR-DE-LIS, a term of blazonry for the flower which resembles an iris, and which, previously to the French Revolution, was borne first semée, and then three, as representing semée, in the arms of France. In old English it was called the *flower-de-luce*. Its origin and history have been variously stated by the French antiquaries. Some have considered it as the flower which grew on the banks of the river Lys, which separated Artois and France from Flanders; others state that Louis VII., who began his reign in 1137, first adopted it in allusion to his name of *Loys*, and because he was called *Ludovicus Florus*, or the Young. The coins of Louis VII. are allowed to be the first on which the *fleur-de-lis* appears, as well as upon his smaller or counter seal. The *fleur-de-lis* were originally borne semée, without regard to number: according to common belief Charles VI. was the first of the French monarchs who reduced them upon his shield to three. Le Blanc, however, remarks that three fleur-de-lis only occur upon the seal of Philip de Valois, as well as upon an impression of a seal of John, King of France, appended to a charter of 1355. Much upon the history of the fleur-de-lis may be seen in Furetière's 'Dictionnaire Universel,' v. 'Lis;' and more especially in Rey's 'Histoire du Drapeau, des Couleurs, et des Insignes de la Monarchie Française,' 8vo, Par. 1837, tom. ii. Upon crowns and the tops of sceptres the *fleur-de-lis* was used by other nations as well as France from a very early period.

FLEXIBILITY is a property of bodies by which they yield transversely, on the application of some power. There is no substance that is not more or less flexible, because there is no substance that is perfectly rigid, and if the rigidity of a body be imperfect it must be to some extent flexible. This property is distinct from ELASTICITY, as it does not necessarily follow that the bodies acted on recover their original figures when the power is removed.

Fibres of wool, silk, hair, and the like, possess this property in a high degree; rods of wood, metal, and stone are flexible, and those of the two last materials are more particularly so when heated. The property is so much the more sensible as the fibres or rods are longer.

When a body instead of yielding and changing its form under the action of a force, breaks, it is said to be *brittle*. These qualities of flexibility and brittleness are present in various degree in different bodies, and under certain conditions either property may be imparted to the same body; brittleness, however, being rather a consequence of hardness than an independent property of matter. If iron, steel, brass, and copper, be heated and suddenly cooled in cold water, they become brittle, but if after being heated they are buried in hot sand, and allowed to cool slowly, they lose their brittleness and become flexible.

The deflexions of beams or bars in vertical and in horizontal positions, when strained by weights, will be noticed under MATERIALS, STRENGTH OF; and the employment of the fibres of hemp and of iron or copper wire in the formation of ropes will be explained under ROPES. Ropes made of metal are said to be even more flexible than those made of hemp, the capabilities of suspending weights being equal, and the former being, of course, less in circumference than the latter.

The mathematical theory for the vibrations which may take place in a thread which is perfectly flexible, when small forces are applied to all its points; and the investigation of formulæ for determining the position and velocities of the points at the end of a given time, may be seen in Poisson's 'Traité de Mécanique,' No. 482, &c., edit. 1833.

FLEXURE, CONTRARY. A point of contrary flexure in a curve is that at which the branch of the curve ceases to present convexity to a straight line without it, and begins to present concavity, or vice versâ. [CURVE.] But when a straight line passes *through* a point of contrary flexure, the curve presents either convexity on both sides or concavity on both sides.

The algebraical test of a point of contrary flexure is a change of sign in the second differential coefficient of either of the two, abscissa or ordinate, with respect to the other. It is frequently stated, in works on the differential calculus, that the sole test of such a point is $\frac{d^2y}{dx^2}=0$, where x and y are the abscissa and ordinate. This is not correct; the above equation may be true when there is no contrary flexure, and there may be contrary flexures when the above is not true. It is necessary and sufficient for a point of contrary flexure that $\frac{d^2y}{dx^2}$ should change its sign, which cannot be except when it is nothing or infinite. Examine therefore all the roots of the two equations,

$$\frac{d^2y}{dx^2}=0 \qquad \text{and} \qquad \frac{1}{\frac{d^2y}{dx^2}}=0$$

and such of them as are accompanied by change of sign give points of contrary flexure.

For instance, let the equation of the curve be

$$y=3x^5-20x^4+50x^3-60x^2$$

$$\frac{d^2y}{dx^2}=60\,(x^3-4x^2+5x-2)=60\,(x-1)^2\,(x-2)$$

then $\frac{d^2y}{dx^2}=0$ when $x=1$ and when $x=2$: but there is only a point of contrary flexure when $x=2$, for when $x=1$ there is no change of sign.

FLEXURE OF COLUMNS. [MATERIALS, STRENGTH OF.]

FLIBUSTIER. [BUCCANEERS.]

FLINT-GLASS. [GLASS.]

FLINTS, LIQUOR OF, is a solution of flint or silica in the alkali potash; it is prepared by fusing together a mixture of four parts of hydrate of potash and one part of powdered flint or fine sand. When a part of the fluid compound is poured out of the crucible, crystals are formed in the residual portion, which, according to Berzelius, are composed of one equivalent of each of its constituents. This compound, sometimes called silicate of potash, silica being regarded as an acid, is soluble in water, and when sulphuric, nitric, or other powerful acids are added to it, hydrate of silica is precipitated.

FLOOK. [ANCHOR.]

FLOOR-CLOTH is made partly of hemp and partly of flax, the former being the cheaper of the two, but the latter better fitted to retain the oil and paint on the surface. As a means of avoiding the necessity for seams of joinings in the cloth, looms are constructed expressly for the weaving of the canvas, of the greatest width likely to be required. As brought to the floor-cloth factories, the pieces of canvas have generally one of three scales of dimensions: 100 yards long by 6 wide, 108 yards by 7, 113 yards by 8. The flax and hemp are spun, and the canvas woven, almost entirely in Scotland, chiefly at Dundee; and the degree of fineness is generally such as to present about 16 or 18 threads to the linear inch.

The canvas, throughout the subsequent operations, retains the same width as was given to it in the loom; but it is cut into pieces varying from 60 to 100 feet long: each of these pieces has to be stretched over a frame in a vertical position; and in most of the factories there is a large number of such frames, some 100 feet long by 18 or 20 high, others 60 feet long by 24 high. As a means of transferring the canvas to these frames, it is, when the bales are opened, cut to the proper length, laid down on the floor of a large room, and coiled round a long wooden roller about 5 inches in diameter; this roller is then lifted up vertically and removed close to the frame; one edge of the canvas is nailed or hooked to one edge of the frame, and the roller is made to travel onwards and to revolve in such a manner as to give off the canvas as fast as the latter can be hooked to the upper horizontal bar of the frame; when all is uncoiled and the canvas hooked on all four of its edges, the sides of the frame are so drawn by winches and levers as to stretch the canvas to a degree of tightness nearly equal to that of a drum, notwithstanding the extent of the surface (from 1500 to 1800 square feet). Here the canvas remains many weeks, during most of the processes.

Before the imprinting of the pattern which forms the most conspicuous feature in floor-cloth, the surface of the canvas requires a great deal of preparation, to render it smooth and durable. The pattern is applied on one surface only; but both surfaces are painted and prepared, the back before the front. A wash of melted size is applied by means of a brush to each surface; and, while this is yet wet, the surface is well rubbed with a flat piece of pumice-stone, whereby the little irregularities of the canvas are worn down, and a foundation is laid for the oil and colour afterwards to be applied. To work over so large an extent of surface, the workmen are provided with narrow scaffoldings, built up in front of, but not in contact with, the surface of the canvas: one scaffold being in front and another behind the canvas.

When the size-preparation is dried, the painting begins. The paint employed consists of the same mineral colours as those used in house-painting, and, like them, mixed with linseed oil; but it is much thicker or stiffer in consistence, and has very little turpentine added to it. The first layer of paint is applied with a trowel; or rather, the paint is dabbed on in large masses here and there, by means of a brush, and then levelled and spread by means of a kind of trowel 12 or 14 inches in length. Ten or twelve days are required for this thick coating to dry; and at the expiration of this time a second coating is laid on, thinner than the former, and applied with a brush instead of a trowel. These two layers of paint are all which the back or hinder surface of the canvas receives; but the front or face receives a greater thickness, and undergoes a greater number of processes. For instance, after the sizing, the surface is rubbed down with pumice-stone; then comes the trowel-colour, followed by a second rubbing with pumice; and then two, three, or more layers of colour, applied with a brush, each coating being followed by a rubbing with pumice before the next one is applied. The surface has by this time acquired a great degree of smoothness, and the general substance suppleness and pliability.

The prepared canvas is next removed from its vertical position in the frame, and wrapped round a roller, which is so placed as to allow the canvas to be uncoiled and spread out on a table to be printed. The printing of floor-cloth is conducted much on the same principle as that of paper-hangings for rooms. [PAPER-HANGINGS.] Both are examples of colour-printing; that is, the successive application of two or more blocks or engraved surfaces, each one giving a different part of the device from the others, and being supplied with paint of a different colour. In the infancy of this art the pattern was given by means of stencil-plates; thin plates of metal or of pasteboard were pierced with holes at the parts intended to form the pattern, and the paint was so applied as to fall through these holes upon the surface of the canvas spread out beneath. It was about a century ago that the use of wood blocks superseded that of stencil-plates for this purpose. The first block so employed was about 15 inches square, and had a simple device of zigzag lines cut upon its surface; when this was pressed face downwards on a cushion coated with wet paint, it took up a layer on all the raised parts of the device, and was then in a fit state to impart its impress to the canvas. The increased complexity arising from the employment of several colours was a feature of later introduction.

As at present conducted, the printing of floor-cloth with several colours requires much care on the part of the designer before the painter enters on his department. In the first place, the device is carefully drawn on the full scale on a stiff sheet of paper, and is coloured fully in every part according to the exact appearance which it is intended to present on the canvas. A second piece of paper is placed under this, and with a pin or pricker a series of holes is made through both papers, following the outlines of the pattern so far as regards one colour, which we may suppose to be green; another blank paper is placed under the pattern in lieu of the former, and the outlines of another coloured portion of the device are marked through both papers with the pricker; and so on as many times as there are colours, the outline of each colour being transferred to a paper distinct from the others. An equal number of blocks of wood are then prepared; these consist of two thicknesses of white deal and one of pear-tree wood, ranged at right angles with respect to the grain, to prevent warping; they are about fifteen inches square, by two and a half in thickness, and the pear-tree surface is the one on which the engraving is to be executed. One of the pricked papers is laid down on a prepared block, and a little bag containing pounce or pounded charcoal is daubed all over it; the powder enters the pin-holes, and leaves upon the surface of the wood a series of dots sufficient to guide the carver in working out the design, which he does by cutting away all the surface except where the lines of device are marked. All the other blocks are treated in the same way; and it is easy to see that each one is left uncut at those parts which are cut away in all the others, so as to avoid confusion of colours.

The blocks (which we will suppose to be four for one pattern, red, yellow, blue, and green) being ready, and the prepared canvas spread out on a flat table, the printing commences. The paint (say red) is applied with a brush to the surface of a pad or cushion formed of flannel covered with floor-cloth; the block, held by a handle at the back, is placed face downwards on this cushion, and the layer of paint thus obtained is transferred to the surface of the canvas by pressing the block smartly down on the latter. A second impression is made in a similar way by the side of, and close to, the first; and so on throughout the length and breadth of the canvas; each impression being about 15 inches square. The proper junction, or register, of the successive impressions is aided by pins at the corners of the blocks. When the whole surface is thus printed with one colour, all the other three are similarly applied in succession. Such would likewise be the case if the number of colours was more than four; but the greater the number the greater would be the care necessary in adjusting the numerous partial impressions so as to ensure a proper arrangement of the whole.

In printing floor-cloth for passages and stairs, where the width seldom exceeds a yard, the canvas is prepared in the frames as in other cases; but it is cut up into strips before being printed, and has usually a border given to its pattern by means of blocks much narrower than those employed in other cases. Where there are large patches of one colour in the pattern of floor-cloth, they are not given by smooth surfaces on the block, but by means of little projecting squares technically called teeth; the reason for this is, that if a surface two or more inches square were laid on wet paint, it would not take up the paint equally, but would exhibit it in an unequal splat; whereas, if the surface were broken up into a number of smaller surfaces by means of lines cut in various directions, these lines would act as air-vents, and the paint would be taken up pretty equally by the little squares or teeth.

One among the features which distinguish cheap oil-cloth (so-called) from good, is the hastiness with which the processes are conducted; the paint has often insufficient time for drying, and is sold for use before it is fitted to bear the friction of the feet. It has been suggested, with some probability, that floor-cloth, especially when thus insufficiently dried, may tend to rot the boards of a flooring in a damp room, by preventing the free escape of vapour.

Mr. Loudon ('Encyclop. of Cottage and Villa Architecture,' p. 345) notices a suggestion for the use of paper instead of floor-cloth or carpet. The carpet, according to this suggestion, is formed in the first instance of any fragmentary pieces of linen, cotton, canvas, or other material, sewn up to the required size. This cloth is stretched on the floor of a large room, and kept down in its place by being pasted round the edges. On this foundation stout paper is pasted; two thicknesses being applied in every part, with the joints so arranged as to be but little perceptible. On this a surface of wall paper is pasted; and here an opportunity for the exercise of taste is afforded, since a variety of pleasing patterns may be obtained by the judicious combination of fragments which are in themselves of very little account. When the pattern is thus far produced, it is coated twice with warm melted size, applied so as to soak into every part of the paper, and to prepare it for the reception of the varnish. One or more coatings of boiled linseed oil are applied after the size, and to the oil succeeds copal varnish. Of the floor-covering so produced it is said, "these carpets are portable, and will roll up with about the same ease as oil-cloth; they are very durable, are easily cleaned, and if made of well-chosen patterns have a very handsome appearance. Where labour is cheap the cost will be very trifling; the materials being of little value, and the expense consisting chiefly in the time requisite to put them together. Where cloth cannot be easily procured, the carpet may be made by pasting paper to painted boards; when by repeated coats of paper it has become strong and firm, it will separate from the paint and will be as durable as if mounted on any kind of cloth. For earth, brick, or stone floors, in order to render them impervious to damp, these carpets may be made with two faces, by pasting paper on both sides of the cloth which forms their basis, and well oiling or varnishing them on the under as well as the upper surface; they may also be bound with leather or any strong substance, to prevent moisture from penetrating to the paste."

It has also been more than once suggested, that 'Geographical carpets' might advantageously be constructed for school-rooms and similar apartments. By this term is meant the employment of a carpet or covering in which the lines of a map are substituted for a regular pattern. There would, as Mr. Loudon has stated, be a good deal of difficulty in working out the idea, since it would have to be decided whether the map should be *printed* before being laid down as a carpet, or filled in by hand afterwards. The choice of material too, whether linen, holland, or paper, would be attended with some difficulty; but such a map, especially if the northern portion of it were directed to the northern side of the room, would not be without its value in rendering the position of a country or district familiar to the inmates of the room.

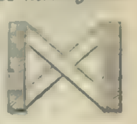
Messrs. Goodyear have recently patented a new kind of floor-covering, intended to combine at once the qualities of durability, softness, elasticity, and cheapness. Carpets are expensive, and not adapted for halls or public rooms; floor-cloth is wanting in softness and elasticity. It was to meet this want that the substance called *Kamptulicon* was invented some years ago. Many persons consider, however, that the kamptulicon, often used the floors of churches and other large buildings, has a tendency to become brittle after some time of usage. Be this as it may, Messrs. Goodyear have devised a mode of combining cork, cotton, wool, and other fibrous materials, with india-rubber, and spreading the mixture upon a back or ground of canvas or woollen. In this state, the carpet or floor-covering undergoes a kind of embossing process, plain or in colours. When thoroughly dried, it is said to have the elasticity and noiselessness of a velvet pile carpet, in addition to much durability.

FLOORS. The platforms which form the separate stories of a building are habitually known by the name of Floors, and they are generally composed of the *ceiling*, the *joists*, and the *floorboards*; great varieties of construction are, however, admitted in each of these details. The various modes of executing ceilings will be discussed under PLASTERER'S WORK, and attention will in this article only be called to the parts of floors which come exclusively within the attributions of the carpenter and joiner.

Floors are either *simple*, or *single-joisted floors*; or *framed floors*. In the former, the ceiling and floor-boards are attached directly to the joists, which are made strong enough to carry the weight likely to be brought upon them, without any intermediate support. In the framed floors, a more complicated system of construction is adopted, for girders are introduced to divide the bearing, and to them are attached, as the case may be, binding-joists, bridging-joists, and ceiling-joists; the two latter of which respectively carry the floor-boards and the ceiling. It is usually considered that a single-joisted floor is, in proportion to the cubical quantity of wood it contains, stronger than a framed floor; but, as Tredgold very properly remarks, when the bearing of the joists becomes considerable, the ceilings of single-joisted floors are liable to be affected by the natural movements of the timber; and at all times it is easier to execute the works required to prevent the transmission of sound in a framed, than it is in a single-joisted, floor. [SOUND BOARDS.]

The weight a floor may have to carry must of course depend upon the purposes it is intended to fulfil. In house floors it is very rarely indeed that a greater weight than 45 lbs. per foot, superficial, can be applied, whilst in common shop and assembly-room floors, it is advisable to count upon a load equal to 80 lbs. per foot, superficial, and in bridges, upon a weight of 200 lbs. per foot; if corn or grain should be stacked upon a floor, it is even desirable to calculate upon a load of 250 lbs. on the superficial foot. Upon these data the strength of the timbers of a floor may be calculated by the formula $w = \frac{b\,d^2}{l}c$; in which w = twice the breaking weight in lbs., distributed over the whole length, or the breaking weight applied at the centre; b = the breadth in inches; d = the depth also in inches; l = the clear length of the bearing in feet; and c = the coefficient of strength of the various descriptions of wood. Tredgold gives, in his 'Elementary Principles of Carpentry,' some more general empirical formulæ for calculating the dimensions of the various details of house floors; and as they are perfectly safe, nay, rather in excess of the absolute requirements of the cases they are designed to meet, they may be unhesitatingly adopted by practical builders. The scantlings of girders he calculates from the formula (No. 1.) $b = \frac{74\,l^2}{d}$; in which b = the breadth, and d, the depth in inches, and l = the length, in feet, between the bearings. The scantlings of binders he calculates by formula (No. 2.), $b = \frac{40\,l^2}{d^3}$; in which the same numeration is preserved. The scantlings of single joists he calculates by formula (No. 3.), $d = 2{\cdot}2\left(\frac{l^2}{b}\right)^{\frac{1}{3}}$; and those of ceiling-joists by the formula (No. 4.), $d = \frac{\cdot 64\,l}{\frac{b}{3}}$. Tables calculated upon these formulæ are given in the body of the work above-quoted, pages 261 to 264.

Practically the limit for the bearings of single-joisted floors seems to be fixed at from 20 to 24 feet; for although it is possible to obtain timbers deep enough to carry the loads of floors of larger spans, yet the depth becomes so considerable as to render the use of double floors preferable, even without reference to the danger and inconvenience arising from the shrinking, or warping, of the joists. The latter inconvenience may be obviated, by the introduction of a system which is now very general in London, known by the name of *herring-bone strutting*, in which the joists are kept in their places by means of cross-struts nailed at the sides of the joists, whose rigidity and steadiness are thus greatly increased. Another practical observation is to be made with respect to single joists, namely, that they must be wide enough to afford a good hold to the floor brnds; perhaps a minimum width equal to one and a half times the thickness of the floor boards used upon them may be admitted.



A span of more than 24 feet in a double floor can rarely be accomplished with ordinary timber girders; and it therefore becomes necessary to resort to the use of Trussed, or of Cast Iron, or of Wrought Iron, Girders. Of late years the latter are almost exclusively used, on account of their greater elasticity, and of their giving considerable notice of their possible weakness. Cast iron, in fact, breaks suddenly under an excessive load, without warning; wrought iron yields gradually. The rules for calculating the strength of metal girders will be found under the head of GIRDERS; they have been derived from the researches of Tredgold, Fairbairn, Barlow, and Hodgkinson.

In France, much attention is paid to the construction of a species of fire-proof floors, in which a framework of H rails, with smaller split rod intermediate bars is formed, and the spaces are filled in with the very energetic plaster obtained by the calcination of the gypsum of the Paris basin. On the top of this artificial landing, sleeper-joists are bedded, and the floor boards are nailed to them, in the better classes of rooms; whilst in the offices, or in the attics, the tiled floors are at once bedded on the joists and filling-in materials. This kind of floor has been imitated in England, and the plaster has been replaced by cement concrete; the principle of construction remaining the same, namely, the formation of an artificial landing, bearing upon the external walls. There are great advantages in these systems of fire-proof floors; but it is to be observed that they load the walls to a dangerous extent, and that in many cases the plaster, or the concrete used, exercises a powerful lateral thrust upon the walls.

The flooring itself is, in England, usually executed of white or yellow deals, or battens; in France, it is almost invariably executed of wainscot, in narrow widths, laid either with a straight joint, or in herring-bone fashion; in Holland and Germany, the ordinary practice is to use wide timber slabs, which shrink and crack in a very disagreeable manner. The boards are usually grooved and feather-tongued, or edge-nailed, in the best descriptions of work; and occasionally, when it is desired to introduce ornamental decoration in the floors, a second layer, composed of variously coloured woods is laid upon a coarser sublayer; the upper layer is usually known under the name of Parquet flooring. The thickness of the single floor boards, or battens, in England, is usually made to range between 1 and 1¼ inches; but the batten floors are rarely more than 1¼ inch thick.

FLO'RA, in the Roman mythology, was the goddess of spring and of flowers, and the wife of Zephyr. A flamen was appointed to her service by Numa. Her temple stood near the Circus Maximus. The *Floralia* were festivals celebrated in honour of Flora, from the 28th of April to the 2nd of May. Instead of the fights of wild beasts, hares and rabbits were exhibited and chased about on those occasions; and women of loose character performed dances and mimic fights, throwing beans and chick-pease among the crowd. The Ædiles presided at these games. (Cicero 'In Verrem,' v. 14.) The ground on which the games were performed is still called Campo di Fiora; it forms one of the squares of modern Rome, and serves as a market-place. Some pretend that the Flora who bequeathed this ground to the Roman people was a mistress of Pompey, the remains of whose theatre are close by. But the floral games were instituted long before Pompey, at the beginning of the 6th century of Rome. They were no doubt originally annual games of the country people. The festival was discontinued for awhile, but was restored in B.C. 173, in consequence of the blossoms of the fruit trees having in that year been severely injured by storms. As long as they were held, the floralia were scenes of the most extravagant licentiousness. The May games and floral games of the middle ages were the direct descendants of the Roman floralia. The term ("jeux floraux") was applied to the more refined poetical assemblies and competition for prizes held at Toulouse. [CLEMENCE ISAURE, in BIOG. DIV.]

FLORIN. [MONEY.]

FLOTSAM, is such portion of the wreck of a ship and the cargo as continues floating in the water. Jetsam is where goods are cast into the sea, and there sink and remain under water; and ligan is where they are sunk in the sea, but are tied to a cork or buoy, in order that they may be found again.

These barbarous and uncouth appellations are used to distinguish goods in these circumstances from legal wreck, in order to constitute which they must come to land.

Flotsam, jetsam, and ligan belong to the crown if no owner appears to claim within a year after they are taken possession of by the persons otherwise entitled. They are accounted so far distinct from legal wreck, that by the king's grant of wreck, flotsam, jetsam, and ligan will not pass.

Wreck has been frequently granted to lords of manors as a royal franchise; but if the king's goods are wrecked, he can claim them at any time, even after a year and a day.

FLOUR; FLOUR-MILLS. Under the heading WINDMILL will be found an account of the mechanism of the windmills employed in grinding flour, raising water, &c., chiefly in the days when the steam-engine had not yet come much into use, or in districts where steam-power is not readily available. Referring to that article for a description of the ordinary mode of producing flour, we shall here treat briefly of certain modern improvements, either in the substitution of steam-power for wind-power, or in the adoption of new forms of grindstone.

In the ordinary mode of grinding wheat into flour, or any other grain into meal (flour being only one kind of meal) there are circular stones employed, each about 4½ feet in diameter; they are flat discs, placed one upon another. The lower one is fixed, while the upper one revolves horizontally on a vertical axis, with a speed of 100 to 120 revolutions per minute. The surfaces are channelled or grooved, to increase their frictional effect; and they are placed so nearly in contact that grains of corn between them are crushed to powder. Now it is found that, owing to the weight (often 14 cwt.), size, and velocity of the upper stone, the flour is much heated before it can escape from the edge of the two stones; it is overground, and is apt to clog into lumps. Millers and millwrights have long sought for a cure for this evil. Some have tried to vary the shape of the grinding surfaces of the stones; while others have sought rather to direct a cold blast of air between them, in order to keep the grain and the flour cool, to separate the grains, to allow all to be acted on equally, and to prevent clogging and pastiness. To insure some or other of these results has been the main object of numerous inventions by Corcoran, Gordon, Taylor, Bovill, Pinel, M'Lellan, Banks, Goodier, Westrupp, Spiller, Valck, Seeley, Schiele, Harwood, White, and others. To notice briefly a few plans is all that need be attempted here.

Bovill's invention comprises five different elements: a mode of driving two ranges of millstones from a central horizontal shaft by means of half-crossed straps, which pass from the horizontal shaft to riggers or pulleys on the vertical spindles of the ranges of millstones; an arrangement for drying meal and flour by means of steam and hot air, instead of kiln-drying the grain previous to grinding; a mode of applying steam to give moisture to manufactured flour, which, after grinding, is in too dry a state; an arrangement for washing grain to separate its impurities, and then drying by currents of hot air; and lastly, a mode of employing machinery in combination with millstones, having apertures covered with wire-gauze or other perforated material, in order to facilitate the passing away of the ground flour through the apertures. All these parts combine to produce a very efficient grinding apparatus.

White's apparatus comprises several new principles. While the upper stone is revolving, the rhyne or connecting piece between the driving spindle and the stone is forced upon its upper side, in such manner as to serve for a rolling or crushing bed for the preparatory crushing rollers. Immediately over this rolling surface are placed the small crushing rollers, adjustable to distance by screws. The grain to be ground passes through a hopper upon the flat rolling surface driven round by the millstone spindle. The revolution of a flat disc rolling-plate causes the two crushing rollers to turn upon their respective axes, and thus to crush the grain as it is fed between the rollers. As the grinding proceeds, the crushed grain falls off the rolling-plate, and reaches the surface of a distributing-plate. The top of this distributor is corrugated radially, to aid in the distribution of the grain. The distributor is made hollow, for the passage of cool air; it has four or five air-holes, which are horizontal curved passages; the outer ends of these holes terminate at the junction of the grinding surfaces, while the inner ends open into a central aperture in the distributor communicating with a descending trumpet-mouthed tube. Air enters by these trumpet-mouths, in consequence of the suction exerted by the chambered air-distributor; the current is strongest just where the grain is most severely acted on and requires most cooling, and then the air escapes by the five or six holes.

In Westrupp's conical mill, there is a conical revolving stone placed *beneath* a fixed stone. The upper stone is a cone, hollow beneath, and the lower one is a cone fitting into it; the two being susceptible of easy adjustment, according to the size and condition of the corn to be ground. On account of the conical form of the rubbing surfaces, the flour leaves the mill very easily. It grinds the corn more completely than an ordinary mill, leaving less farina in the bran; for the bran remains awhile after the flour is expelled, and then falls by gravity to another pair of stones, where the remaining farina is ground out of it. It has been asserted that this mill obtains one shilling's-worth more of flour from a quarter of corn than the ordinary mills, and that the flour is better in quality; but this is a statement requiring confirmation.

Schiele's anti-friction corn-mill is an application to practical purposes of a peculiar curved surface, which Mr. Schiele discovered; or rather, a concave revolving surface rubbing against a convex fixed surface, to prevent a kind of irregular friction which results from the contact of conical surfaces. The gradual variation of the curvature, in relation to the increasing distance of the parts from the centre of motion, equalises the rubbing pressure. The wear upon the stones is uniform in all parts; and it is expected by the inventor that there will be no need to re-dress the stones until actually worn down many inches equally all over.

M. Falguière, a Frenchman, has invented a mill comprising a pair of vertical stones revolving at high velocities; they weigh together less than 1 cwt., and are made small and portable for use in camps and ships. The grain is fed down from a hopper into a horizontal cast-iron pipe, with an Archimedean screw inside; the screw carries it to the other end of the pipe. The stones are fixed in a pair of frames, surrounded by a copper casing in two hinged halves. The running stone is carried upon a separate shaft driven by a band. The stones are concave at their travelling surfaces, and the grain is conveyed into this space from the tube.

The *gruaux* flour of M. D'Arblay attracts much attention on the continent of Europe, on account of the great extent to which the finest and most nutritious part of the flour is retained. Hard wheats of all kinds, especially Sicilian, Russian, and Sardinian, from the large per centage of gluten which they contain, are the best adapted for the gruaux principle of grinding. The grain is first ground in a mill; the white middlings are then separated by course sieves and re-ground; and, finally, the flour is repeatedly passed through fine silk sieves. The flour produced by this tedious and expensive process is of the very finest description, especially for *pâtes* and the most delicate bread. The average produce of flour thus obtained is only 25 per cent. the weight of the grain; therefore, it is necessarily high in price.

We may here notice a singular mode of drying grain adopted by Messrs. Kennedy and Armstrong at Lisburn, in Ireland. They employ an old shot-tower, in which perforated plates are fixed in a zigzag direction from top to bottom; hot air is admitted to the under surface of each plate, and grain falls on the upper surface. Down these plates the grain passes; and, by an ingenious contrivance, at the zigzag corners it is turned over during its passage, so as to be acted on equably. The speed of descent and the heat of the air can be regulated according to circumstances. The weight of the grain turns a discharging wheel at the bottom; and a pendulum, attached to the wheel, regulates the rapidity of the discharge of the grain, and also acts as a meter of quantity. This mode of drying grain is found to be cheap, easy, and healthy, irrespective of any particular mode of grinding the corn into flour.

An experiment in corn-grinding of a very important kind was made during the Crimean war, affording testimony which may be, and certainly ought to be, suggestive of improvements in our army and navy services. In order to lessen the difficulties in the way of supplying bread to the troops, the British government sent out to Balaklava two steamers, one fitted up with machinery for grinding corn, and the other with baking ovens. Mr. Fairbairn, the engineer, being consulted, he prepared plans and drawings of the requisite machinery. The government purchased the Bruiser and Abundance steamers; and in three months all the fittings, novel as they were, were completed. The mill was capable of grinding 20 bushels of flour per hour, even while the steamer was moving at 7 or 8 knots an hour. The steamer and the mill were both worked by the same steam-engine, made by Robert Stephenson. When the two steamers reached Balaklava, about the end of 1855 or early in 1856, the Bruiser was at once set to work as a corn-mill; it ground 24,000 lbs. per day, taking any kind of corn that happened to be procurable, and never got out of order during three months' operation. The flour produced from this weight of grain was made up into 18,000 lbs. weight of 4 lb. loaves, served out daily to the troops. So few were the interruptions in this course, that in the first three months of 1856 the mill ground 1,800,000 lbs. of corn, yielding 1,330,000 lbs. of flour (the rest being bran and waste). The total cost of the wheat and grinding the flour was about one penny per pound. It does not fall within the province of the present article to notice the arrangements of the bread-making and baking apparatus; but it may suffice to say that the Abundance baked into bread all the flour which the Bruiser could grind. The steamers and the machinery were sold at a small price when the war was over; but the lesson afforded is not likely to be lost. A competent authority has observed: "The experiment forcibly suggested the necessity of a light portable steam-engine and mill for grain being constantly attached to the camp when an army takes the field. This could be done at a very moderate cost. The whole affair need not exceed the weight of a large-sized gun, such as now accompany our armies. There is no practical difficulty in the way of introducing an engine capable of supplying newly-baked bread from an oven constructed in the smoke-box of a portable locomotive engine, mounted on wheels, and prepared with grinding apparatus at the same time." Some recent experiments on army cookery, made at Woolwich, induce a hope that corn-grinding and bread-baking vehicles will by and bye be attached as regular component items in the *matériel* of an army.

Some of the flour-mills recently constructed are establishments maintained on a very extensive scale. One, on the banks of the Thames near Blackfriars Bridge, contains 32 pairs of millstones and 16 dressing-machines. All the movements are effected by steam-power, and great ingenuity is displayed in every part of the arrangements. The Americans, also, have begun the application of machinery on a large scale to the grinding of flour, not only for home consumption, but for export to England. Some of the millers in the United States adopt a singular mode of filling the flour-sacks. A trough is suspended on an axis; and beneath one end of the trough is a pair of scales, or rather the flour-pan of a pair of scales. The flour-barrel is placed on the scale-pan; flour flows through the trough into it; and when the proper quantity has been thus precipitated, and the scale-pan and barrel have descended by their weight, a small piece of apparatus catches hold of the trough, and tilts it into the contrary direction, so that no more flour can flow through it into the barrel. The apparatus thereby effects the double purpose of filling and weighing.

The flour sold in the London market is sometimes adulterated, but not to so great an extent as some other articles of food. Dr. Normandy says that "The physical characteristics of wheat-flour of good quality are the following: It has a dull white colour, somewhat inclining to yellow. It should exhibit to the eye no trace of bran, even when pressed smooth with the hand or with a polished surface. It should have a homogeneous appearance, and should not lose more than from 6 to 12 per cent. after drying in a stove; the less it loses by drying the better it is." The adulteration of flour, when it exists, is usually made by means of potato starch, bean flour, Indian corn flour, and rice flour; these are innocuous, and the dishonesty consists mainly in selling these cheap substances at the price of good wheaten flour. Some of the adulterants, however, are less innocent; such as alum, chalk, bone-dust, and plaster.

It is not necessary to enter in this place into the subject of the flour-trade, sufficient on that matter having been given in the article Corn-Laws and Corn-Trade. The relative quantities obtained from different countries vary widely and rapidly, owing chiefly to the fluctuating richness of the harvests.

FLOWERS. A term invented by the alchemists, and still in use, to denote the light flocculent sublimates obtained by heating volatile solids in close vessels; for instance, flowers of sulphur, benzoin, and antimony.

FLUE. [House.]

FLUENTS. [Fluxions.]

FLUID. This term is applied to substances of which the parts possess perfect mobility amongst themselves, but more rigorously it depends on the relative intensities of the forces which act on the component particles of masses. In bodies of permanent form, denominated *solids*, these forces not only preserve the particles in a state of rest when undisturbed but also, on the communication of a slight disturbance relative to their mean positions, reduce them, after the lapse of a very short time, to the places they possessed before; hence arises the permanence of figure and arrangement characteristic of solid bodies. On the other hand, the gases have an elastic or expansive power, which is usually attributed to caloric, because the gaseous state is induced in all substances by the communication of a high degree of heat; the particles of gases have therefore a tendency, when external forces are removed, to fly from their places in obedience to the repulsion exercised by the parts in their vicinity; they are therefore freely movable amongst each other. But the conditions of the motion of any one particle are nevertheless limited by the condensations of the particles on which they impinge, and the rarefactions of those which they abandon, and therefore, even in a gas, the disturbance of a particle only makes it describe a curve round its mean position, and the condensations and rarefactions thence generated produce inequalities of pressure which propagate like motions in the particles in the vicinity. These motions, gradually conveyed throughout the entire mass, produce vibrations, the phenomena of sound, and, it is thought, those also of light.

This yielding to the internal forces called into play by the motion of the particles of a gas is by no means opposed to but rather implies their perfect mobility. If we diminish or increase their specific weight by an alteration of temperature, they will accordingly rise or sink amongst the myriads of particles by which they are surrounded. Yet they will not rise or sink as if in vacuo, for they still will be encumbered by the influences of the adjacent particles, and therefore their motions must suffer resistance.

But in liquids, which also come under the denomination of fluids, this alteration of density and elasticity is imperceptible in ordinary motions, from whence, in physico-mathematics, they have been generally treated as incompressible bodies; still a small alteration of specific gravity is sufficient to produce a distinct motion on the particles subject to such change. By the application of a blow-pipe to the lower part of a glass vessel containing any liquid, a current, due to the alteration of density of the particles in contact with the heated part of the glass, is generated, and there is much reason to believe that many of the permanent currents of the ocean originate from a similar cause, namely, the unequal temperature of different parts of the bottom of the sea, either from the difference of their depths, or of the conductibility of the solid strata with which the fluid is in contact.

The particles of a fluid being thus surrounded by others which are subject to external forces, such as that of gravity, undergo a pressure which is estimated by considering how great it would be if continued uniform over any surface taken as a unit. The direction of such a surface is immaterial, for the particle can only be in repose when the pressures from all quarters are equal. When fluids are inelastic this pressure is entirely due to extraneous forces, such as the weight of the superincumbent mass; but in elastic fluids, as in air, the pressure is necessarily proportional to the elasticity of the particle which supports it; and this elasticity is known to increase with the diminution of the volume compressed; such fluids therefore, under the influence of external forces, acquire variable densities in their different parts.

We reserve for the articles Hydrostatics and Hydrodynamics the principles from whence the equilibrium and motion of fluids are deduced when subject to known forces; and for the article Tides the case when those forces are the attractions of the sun and moon upon the ocean.

The equilibrium of a body floating on a fluid depends on two simple conditions; namely, that the centre of gravity of the whole body and of the displaced fluid must be in the same vertical line, and the weight of this displaced fluid must be equal to that of the body: but for the conditions of the stability of the equilibrium we refer to Metacentre.

When a body moves in a fluid it suffers a resistance depending on its velocity; and when the body is small compared with the mass in which it moves the law of resistance is nearly expressed by the square of the velocity. This hypothesis was originally formed by considering that the number of particles on which the moving body impinges in a given time is nearly proportional to its velocity: we say nearly, because the particles which have been struck form returning currents which interfere with this simple law; and, secondly, that the force with which it impinges is also as its velocity, which must be modified from the same consideration. The nature of these currents has not been yet investigated, and therefore the law of the square of the velocity is adopted generally as a first approximation, but the discovery of the true law would appear to be within the limits of calculation without aid from experiment, and is a subject worthy the attention of physical mathematicians.

The resistance of bodies only partly immersed in fluids, and having a depth bearing a sensible ratio to that of the fluids, as in barges towed along canals, is subject to laws far different from those which we have considered, for the quantity immersed is itself a function of the velocity, diminishing considerably with great velocities: thus, notwithstanding the increase of resistance due to velocity, this diminution due to less immersion permits the possibility of a minimum resistance. This important subject will be further considered in the article Hydraulics.

The term fluid has been extended to the supposed media through which the forces of electricity, galvanism, and magnetism act, but little that can be relied upon has been deduced from their supposed analogy with material fluids. [Electricity.] A surer source of calculation is found in detecting the laws of their elementary actions by experiment; and indeed this process seems to point out the most feasible methods for discovering the molecular laws even of material fluids, manifested both in their tenacity and their capillary phenomena.

Fluidity cannot be easily defined in the explicit terms of its exact causes until more is known of the true laws of the forces which govern the internal arrangement of bodies; but taking the effect, we may with Laplace say, that "mobility is the characteristic property of fluids." Hence fluidity may be rendered imperfect by the admixture of solids with fluids, as in mud, &c. The effects of fluidity become still more concealed in masses consisting of heterogeneous solids holding fluids in their pores, as in moist clays, dough, &c.; nor are they fully developed in solids which, through the action of heat, are tending to a fluid state, as in melting tallow, wax, glass, &c. In none of these cases can the laws of perfect fluids be applied; but as they belong only to states of transition, their peculiar laws do not deserve, or at least have not obtained, much consideration.

FLUIDITY. All ponderable matter exists either in the gaseous, fluid, or solid state; and most solids, when heat is applied to them, may be rendered fluid, or converted into liquids, under which circumstances mutual repulsion of particles takes the place of cohesion. The degree of heat required to produce this effect is different in different solids, but, *cæteris paribus*, it is always the same in the same solid: in many cases the transition from the solid to the fluid form is sudden, while in other instances solids pass through various degrees of liquidity before they become perfectly fluid. Of the first mode of becoming fluid ice and the metals are examples, and wax or tallow of the second.

As most solid bodies may be rendered fluid by heat, so many gaseous and fluid bodies are converted into solids by diminishing their temperature. Solid bodies in becoming fluid render latent a large quantity of heat; and on the other hand, fluid bodies in becoming solid evolve much sensible heat. The heat which is requisite to the fluid existence of a body is termed the *heat of fluidity*. These facts are proved by two simple experiments. Mix a pound of water at 32° Fahr. with a pound of water at 172°, and the resulting temperature will be the mean, or 102°. If a pound of ice at 32° be dissolved in a pound of water at 172°, the solution will not have the mean temperature of 102°, but only 32°. As, then, the pound of ice, by being rendered merely fluid, absorbs 140° of heat, so the quantity of heat which becomes sensible when a pound of water at 32° is converted into ice at 32° amounts also to 140°. The actual quantity of heat rendered latent by different fluids as they liquify depends upon the nature of the substance; thus, according to Person, the under-mentioned bodies contain the annexed quantities of heat in the latent state when rendered fluid:—

Water	142·65 Fahr.
Nitrate of Soda	113·34
Nitrate of Potash	85·26
Zinc	50·63
Silver	37·92
Tin	25·65
Cadmium	24·44
Bismuth	22.75
Sulphur	16·85
Lead	9·65
Phosphorus	9·05
Mercury	5.11

The nature of fluidity will be further considered under Heat.

FLUIDS, ELASTIC. This name may be applied to all fluids in nature, since all are in certain degrees elastic; but it belongs particularly to such as are aëriform, liquid substances possessing the property of elasticity only in a low degree. [Elasticity; Peizometer.] Among the aëriform fluids, however, those which are usually considered as permanently elastic are called *gases* and the term *elastic fluid* is frequently confined to atmospheric air, and the vapours which are produced from solids or liquids by the action of heat; these last are therefore such as may be rendered solid or liquid by reducing their temperature, or by increasing the pressure under which they exist. But the difference between these and the fluids which are called *permanently elastic* is perhaps nominal, since many of the latter, by the discoveries of Dr. Faraday, are found capable of being exhibited in a liquid form. [Gas.] This philosopher, for example, obtained carbonic acid in a liquid state from carbonate of ammonia, by subjecting it to great compression in a sealed tube, one end of which was placed in a freezing mixture. The liquor was colourless. This gas, with some others, have also been reduced to the solid form. Many of the gases, moreover, on being combined with one another and with other substances, form solids or liquids; thus, oxygen gas unites with metals and becomes solid; ammoniacal gas and hydrochloric acid gas unite and form the solid hydrochlorate of ammonia; while oxygen and hydrogen gases unite to form water.

Almost all gases are invisible; but several which are so when they exist alone, become visible on being mixed with one another. Thus, binoxide of nitrogen being mixed with atmospheric air, the combination becomes visible and of a red colour. Several gases also become visible when mixed with aqueous vapour. An augmentation of the temperature of vapour may, by producing an increased rarefaction, render it invisible; and, on the other hand, a diminution of temperature will cause such a condensation as may render visible a vapour which before was imperceptible. These effects of heat and cold upon vapour have been proposed as explanations of the apparent diminution of the mass of a comet when near the sun, and of its apparent enlargement in receding from that luminary. All elastic fluids are transparent, but different quantities of light are absorbed in passing through those of different kinds, and when the thickness of a stratum of fluid is considerable, the absorption is so great as to render an object beyond it invisible.

The elastic forces of a dry gas at a given temperature are inversely proportional to the volumes they occupy; and this law holds good also both for mixtures of elastic vapours with each other, and of vapours with gases, provided no chemical action takes place between them. Thus, different fluids of equal temperatures and equal elastic forces being introduced together in a close vessel whose capacity is equal to the sum of the volumes of the fluids separately, the fluids for a time remain separately in equilibrio; but experience shows, that gradually the fluids intermingle with one another, producing a homogeneous fluid preserving the same temperature and elastic force. It has been found also that if different fluids having equal temperatures with different elastic forces, and occupying separately equal volumes v, be mixed together in a close vessel whose capacity is v, the elastic force of the mixed fluid will be equal to the sum of the elastic forces of the separate fluids, and the temperature will remain constant. When a vapour at a given temperature is compressed by being confined within a smaller space than that which it previously occupied, part of the vapour becomes condensed, and the remainder continues to possess the elastic force due to the temperature. And again, if the volume of a quantity of vapour be increased, the vapour will expand, and, if not in contact with the liquid from which it was produced, its elastic force will be diminished; if in contact with the liquid new vapour will rise to supply the void created by the dilatation, and the elastic force will remain constant.

The temperatures at which liquids become elastic fluids by the action of caloric are very various; hydrochloric and nitric ethers boil, under the usual pressure of the atmosphere, the one at 51·9°, and the other at 185°; acetic ether boils at 165°; water boils at 212°; while mercury can be made to boil only at a temperature of 662°.

The quantity of vapour produced by heat from a liquid increases with an increase of temperature, and while in contact with the liquid its elasticity varies with its specific gravity. The elastic force of vapour is increased when the vapour is mixed with air; for if the interior of a barometer tube be moistened at the upper end with water, and air be introduced in it above the column of mercury, the tube being inserted as usual in a cistern of the latter fluid, the depression of the mercurial column in the tube by the expansion of the vapour and air, in consequence of an application of heat on the exterior, is greater than that which results from the expansion of air when dry.

The atmosphere which surrounds the earth is endowed with an elastic power; and partaking, moreover, of the earth's diurnal rotation, its particles should, by their elasticity and centrifugal force combined, recede from the earth till the whole is dissipated in space. Such is not the fact; and hence it is inferred, either that at a certain elevation above the surface of the earth the elasticity of the atmosphere is totally destroyed by the absence of caloric; or that beyond the stratum in which the centrifugal force of the particles is equal to their gravitation, there may exist, in a state of rest, an ethereal fluid occupying the whole extent of space, and preventing the atmosphere from being further expanded by its own elasticity.

Now, by mechanics, it may be found, that the distance from the surface of the earth to the stratum of the atmosphere in which the centrifugal force of the particles is equal to their gravity is about five semi-diameters of the earth, at which height the density must be inconceivably small; and since it is not necessary to suppose that the ethereal fluid beyond the atmosphere of the earth is more dense or more elastic than the atmosphere at that height, it may readily be admitted, that whatever may be the effect of such a fluid in resisting the motion of a comet, it can produce no sensible retardation of the movements of the planets.

The crepuscular light which has been observed at the cusps of Venus, and the changes which take place on the apparent discs of Mars and Jupiter, afford indications that those planets have atmospheres, though, with our instruments, such atmospheres may not be rendered sensible by their action on transmitted light. If, about a planet, an atmosphere were formed in consequence of the attraction exercised by the planet on the ethereal fluid supposed to fill all space, since that fluid may have no greater density and elastic power than the atmosphere of the earth at the height of five semi-diameters of the latter above its surface, the attraction of the planet may be incapable of rendering it sufficiently dense to produce any sensible effect in refracting light to the earth. Again, the height and the law of the variations in the density of the strata in an atmosphere which may be formed about a planet by the vapours arising from waters existing on its surface, would depend on the temperature; and this we have no means of knowing: but assuming it to be equal to the mean temperature at the surface of the earth, the height of such atmosphere would be very small compared with that of the existing atmosphere about the earth. An atmosphere of either of the kinds here indicated would serve to account for the rare occurrence of remarkable refractions in the phenomena of the immersions and emersions of Jupiter's satellites, or the occultation of stars by the moon.

For the properties of elastic fluids, see also ELASTICITY; AIR; GAS; VAPOUR; and EVAPORATION.

FLUOBORIC ACID. [FLUORINE.]

FLUORESCENCE (from fluor spar), is a term which has recently been employed to designate a phenomenon the nature of which remained till lately unknown.

It has long been known that certain substances have the property of yielding solutions which, though perfectly bright by transmitted light, exhibit a sort of coloured opalescence by reflected light, quite different from the transmitted colour. The bark of the horse-chestnut, for instance, contains such a substance, to which, on account of the property, the name *Schillerstoff* was formerly given by some German chemists. Sir David Brewster discovered that on admitting a beam of sun-light condensed by a lens into an alcoholic solution of the green colouring matter of leaves, the path of the rays in the fluid was visible as a beam of blood-red light. This phenomenon, which he designated *internal dispersion*, and which he seems to have attributed to the reflection of light from suspended particles, he has observed and studied in a great many instances, among many others in the case of a green variety of fluor spar, which appears deep blue by reflected light. This blue colour Sir David showed is not superficial, but arises from internal dispersion. ('Edinburgh Transactions,' vol. xvi., part 2, reprinted in the 'Phil. Mag.' for June, 1848.)

In the 'Philosophical Transactions,' for 1845, Sir John Herschel describes a remarkable phenomenon, which he discovered in relation to the blue colour exhibited by dilute solutions of salts of quinine. The blue colour, he found, came mainly from a narrow stratum adjacent to the surface by which the light enters the fluid, but the blue rays thus produced traverse the fluid freely. The incident light, however, after having once passed through a portion of the fluid of very moderate thickness, although apparently unchanged, has undergone some mysterious analysis, whereby it is rendered incapable of again producing a similar blue stratum in another portion of the solution on which it falls, or of causing the deep blue reflexion at the surface of the green fluor above-mentioned.

In reflecting on this peculiar analysis of light discovered by Sir Sir John Herschel, Professor Stokes was led to discover that the blue light shown by solutions of quinine is produced, not by the blue rays of the spectrum, but by the more refrangible and mostly invisible rays which are known to exist. ('Phil. Trans.' for 1852, p. 463.) The most direct mode of proving this by experiment consists in forming a pure spectrum [DISPERSION OF LIGHT], and placing in it the solution of quinine. Commencing about the middle of the violet, and extending from thence onwards far into the region of the more refrangible invisible rays, the path of the incident rays within the fluid is marked by a sky-blue light, which emanates in all directions, as if the fluid were for the time being self-luminous. The blue rays produced exhibit on analysis a continuous spectrum within certain limits. They have the properties of other blue rays of like composition, and accordingly freely traverse the fluid, which is transparent with respect to blue light. The invisible rays, however, by which the larger part of the effect is produced, are absorbed with great energy, and thus it is that the light which has traversed a moderate thickness of the fluid is unaffected when judged of merely by the eye, on account of the invisibility of the rays of which it is deprived, and yet has lost its property of producing the blue stratum in a solution of quinine. Inasmuch as the incident rays are absorbed, and in their stead there issue in all directions, from the part of the fluid in which the absorption takes place, rays of a different refrangibility, the effective portion of the incident light may be said to have *changed its refrangibility*, an expression which briefly indicates the most striking of the observed facts of the phenomenon.

This change of refrangibility, when once suggested, proved to be extremely common, and to embrace the more striking instances of internal dispersion mentioned by Sir David Brewster: among others, that of the variety of fluor spar, of which mention has already been made. When a *fluorescent* body (or one which possesses the property in question) is examined in a pure spectrum, it is found that, beginning at a point of the spectrum varying with the substance examined, and continuing from thence onwards in the direction of increasing refrangibility, the incident rays in being absorbed cause the substance to emit rays of a different refrangibility, which observation shows to be *always lower* than that of the active rays. The colour of the emitted rays depends only on their refrangibility, having no relation whatsoever to the colour of the active rays, or to the circumstance of their belonging to the visible or invisible part of the spectrum. Thus, fluorescent substances, by emitting light under the influence of the invisible rays, render the presence or absence of such rays, and in case of their presence their course, a matter of direct ocular inspection, and in this sense they may be said to render visible the invisible rays. The appearances thus produced are in many cases very striking to witness, and several remarkable effects may be produced by ordinary daylight, by the aid of absorbing media (see 'Phil. Trans.' for 1853, p. 385). It is readily shown also that glass is opaque with regard to the rays of very high refrangibility, but quartz transparent; and by using prisms and a lens in which quartz takes the place of glass, the solar spectrum is shown to extend to a distance, measured from the extreme red, more than double the length of the visible spectrum; while with the electric light a spectrum is obtained no less than six or eight times as long as the visible spectrum. ('Proceedings of the Royal Institution,' Feb. 1853.)

As to the cause of fluorescence, Professor Stokes supposes ('Phil. Trans.' for 1852, p. 548) that the incident ethereal vibrations agitate the ultimate molecules of the sensitive bodies, and that these molecules in turn became new centres of disturbance, from whence emanate in all directions ethereal undulations agreeing in their periodic times, not with the periods of the vibrations which produced the effect in the first instance, but with the periods in which the molecules are disposed to swing. This supposition entails the supposition of a certain duration in the effect, equal at least to that of a great number of vibrations; but as many hundred millions of millions of luminous vibrations take place in one second, such a duration may very well exist while the phenomenon is yet as to sense instantaneous.

M. Edmond Becquerel, who has studied so carefully the closely allied phenomenon of phosphorescence, has recently devised a very ingenious instrument, which he calls a *phosphoroscope*, adapted to the study of phosphorescence of short duration, and to the detection of a finite duration of the effect in cases of fluorescence ('Annales de Chimie,' tom. lv. p. 5). With this instrument M. Becquerel has succeeded in demonstrating, in the case of crystallised nitrate of uranium and many other substances remarkable for their powerful fluorescence, the existence of a powerful phosphorescence of short duration. Although a finite duration in the luminosity has not yet been detected in the case of any liquid, these researches go far to demonstrate experimentally that there is no definite line of demarcation between phosphorescence and fluorescence, but that fluorescence is merely phosphorescence of very short duration.

It is remarkable that in a paper published in the year 1842 ('Phil. Trans.' for 1842, p. 194), Sir John Herschel mentions an extraordinary prolongation of the spectrum when received on paper washed with tincture of turmeric, which however he supposed to be due to the visibility of the highly refrangible rays, *as such*. In a paper published in 1843 ('Annales de Chimie,' tom. ix. p. 320), M. Becquerel mentions a phenomenon which he had frequently observed in the course of his researches on phosphorescence, namely, that when a spectrum was thrown on certain papers, prepared with phosphorescent substances, the more refrangible and usually invisible part situated beyond the violet was rendered visible by the screen, but only so long as the light fell upon it. This phenomenon, he suggests, may consist in a brilliant phosphorescence of short duration; but apparently from connecting it too closely with the previously known instances of phosphorescence, he failed to perceive its full bearing, and never suspected that the blue colour exhibited for instance by a dilute solution of sulphate of quinine, a fluid whose absorbing action on the invisible rays he studied by means of photography, and whose dichroism he expressly mentions (p. 289), was actually produced by the invisible rays.

FLUORIDES. [FLUORINE.]

FLUORINE (F), a substance which, though long known in combination with other bodies, has been only lately procured in an insulated state, if indeed as much as this can be said, and its properties in a separate state are consequently very imperfectly known. It was first obtained, or at any rate supposed to be obtained, in a separate form by Baudrimont, by passing fluoride of boron over deutoxide of lead, heated to redness: the gas was received in a dry vessel. Although little is known of fluorine in an elementary condition many of its compounds have been studied. Those which it forms with the metals will, if of sufficient importance, be found described under the respective metals. The following are the chief remaining compounds of this element:

Hydrofluoric Acid (HF), a compound of fluorine and hydrogen, which was first made known by Scheele. Mr. Knight ('Phil. Mag.,' xvii., p 357) first suggested an apparatus for procuring it in a state of purity, though not of the greatest strength. The properties of this acid were minutely examined by Gay-Lussac and Thenard in 1810. ('Recherches Physico-Chimiques.') Fluor-spar, or what is more correctly termed fluoride of calcium, is to be mixed with twice its weight of strong sulphuric acid, and put into a leaden or silver retort, to which a receiver of the same metal is to be adapted, and surrounded with ice or snow mixed with salt. When a moderate heat is applied to the retort the sulphuric acid acts upon the fluoride of calcium, in a mode analogous to that in which its action is exerted upon common salt in preparing muriatic or hydrochloric acid; the results are sulphate of lime, which remains in the retort, while the fluorine of the fluoride uniting with the hydrogen of the decomposed water of the sulphuric acid forms hydrofluoric acid, which, coming over in the state of vapour, is condensed in the cooled receiver; the product is best kept in a silver bottle with a stopper of the same metal.

The properties of this acid are, that it is fluid, clear, colourless, and volatile; and when it escapes into the air, it forms with the atmospheric moisture white fumes, as hydrochloric acid does. Its vapour is extremely pungent and irritating, and it acts strongly on vegetable blues. The specific gravity of hydrofluoric acid is 1·0609, but by the gradual addition of a certain quantity of water, the density may be increased to 1·25. Its attraction for water is very great, and when dropped into it they combine with a hissing noise. The liquid acid is extremely corrosive; when a drop is allowed to fall upon the skin it produces painful sores. Until recently the concentrated acid here described was supposed to be anhydrous, but it is now known to contain water, which may be removed by the addition of anhydrous phosphoric acid, the true anhydrous acid then escapes as a colourless gas of a very irritating odour and which by means of a freezing mixture may be condensed to a colourless mobile liquid.

The reason for the necessity of distilling and keeping this acid in metallic vessels is that it acts upon and decomposes glass with great facility, on account of its great affinity for silica which the latter contains. Hence it has been rendered extensively useful for ornamental etching upon glass.

When hydrofluoric acid is brought into contact with certain metals it is decomposed, hydrogen gas being evolved, and a metallic fluoride formed: upon potassium this action is extremely energetic, and is attended with the evolution of gas and the formation of fluoride of potassium. With metallic oxides it forms a fluoride and water.

Hydrofluate of ammonia may be obtained by saturating the acid with the alkali; it is an unimportant salt, not being applied to any purpose whatever.

Fluoride of Silicon, (SiF_3) sometimes improperly termed *Fluosilicic acid*, is prepared by mixing equal quantities of fluoride of calcium and silica with three times their weight of sulphuric acid in a retort; on the application of a moderate degree of heat action takes place; and it appears that the oxygen of the silica is transferred to the calcium of the fluoride and converts it into lime, which combining with the sulphuric acid forms sulphate of lime, while the fluorine and silicon set free combine to form fluoride of silicon, which rises in the gaseous state, and is to be received in very dry air-jars filled with and inverted in mercury.

The gas thus obtained is colourless, its odour is peculiar, suffocating, and acid, and it fumes on coming into contact with the moisture of the air, but much less so than fluoboric acid gas. Its specific gravity, according to Dr. Davy, is 3·600, while Dumas makes 3·574. It suffers no change by exposure to a high temperature, and it has not been liquefied by condensation. It is absorbed and decomposed by water, forming a solution which contains a peculiar acid,—the *hydrofluosilicic* acid ($3HF, SiO_3$).

When potassium is put into this gas, it inflames and burns. When the gas is passed over iron heated to whiteness, there is formed an extremely thin coating of fluoride of iron and silicium, and the gas then passes without further alteration.

It does not decompose the alkaline carbonates when dry at common temperatures, nor is it absorbed by them, however long they may remain in contact; most hydrated oxides however absorb it without the assistance of heat.

Fluoride of silicon condenses double its volume of ammoniacal gas, and forms with it a volatile compound, which is of no importance; when it acts upon metallic oxides both are decomposed, the results being silica and metallic fluorides.

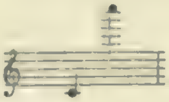
Fluoride of Boron, (BF_3) improperly termed *fluoboric acid*, was obtained by Gay-Lussac and Thenard by heating a mixture of fluor-spar, or fluoride of calcium, and vitrified boracic acid. In this operation the oxygen of the boracic acid combines with the calcium of the fluoride of calcium and converts it into oxide of calcium or lime, and the fluorine and boron then uniting form the compound in question. The properties of this gas are, that it is colourless, has a pungent odour, is deleterious to animals, and extinguishes flame. It reddens litmus paper strongly; and when bubbles escape into the air, they combine with its moisture and produce a very white dense fume. Water dissolves about 700 times its volume of this gas. The solution is strongly acid, and emits fumes, and is found to contain *hydrofluoboric acid* (HF, BF_3). This solution does not act upon glass, nor does the gas itself; but they readily decompose animal and vegetable substances. Thus, a piece of paper put into the jar of the gas over mercury is decomposed and charred as if burnt, by the abstraction of the elements of water from it, for which the gas has so powerful an affinity. When potassium is put into this gas it burns, and a brown mixture of boron and fluoride of potassium is obtained.

FLUOSILICIC ACID. [FLUORINE.]

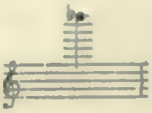
FLUTE, a well-known musical instrument, the use of which, under different forms and names, may be traced to the remotest periods of antiquity. Most of the ancient poets ascribe its invention to no less personages than gods and goddesses. Even the grave Plutarch, in his dialogue Περὶ Μουσικῆς, attributes it to Apollo. Lucretius, however, contents himself by deriving its origin from the breathing of western winds over certain reeds, and thus, he tells us, was suggested to man the rural pipe, a simple tube, which the ingenuity of later ages has improved into one of the most elegant and fascinating instruments of which art can boast. The word is said to be derived from the Latin *fluta* (lamprey), a kind of eel which has seven holes lengthways in its side, and when extended resembles a very narrow flute.

The ancient flute had some sort of mouth-piece; it was double as well as single—that is, was often composed of two tubes, both played together, and hence it has not unreasonably been inferred that the enlightened nations of antiquity possessed some knowledge of harmony. There is a figure of an ancient flute-player, or a terminal Pan, in the Third Græco-Roman Saloon of the British Museum. The flute was almost universally employed by the Greeks, Romans, &c., not only in their temples, theatres, social entertainments, and armies, but also in their funeral ceremonies. It even may be said to have accompanied their public orations, having frequently been employed for the purpose of keeping the voice up to a proper pitch. From the custom of introducing it in the last offices for the dead arose the saying, *Jam licet ad tibicines mittas* (you may now send for the flute-players), when any one was *in articulo mortis*—in the last agonies.

Of the old English flute—for the invention whereof Mersenne erroneously gives this country the credit—we will say a few words. It was not unfrequently called the *flute à bec*, from the resemblance of the mouth-piece to the beak of a bird. This mouth-piece was at the upper and wider end, and the instrument was held in the manner of the oboe and clarionet. It had seven finger-holes, no keys, and was commonly adapted either to the scale of C or F. The *flute à bec* was gradually superseded by that now in use, which long was known as the German flute—the *flute traversière*, or horizontal. This, at first simple in construction, limited in means, in length about a foot and a half, and having only one key, has by degrees been extended to twenty-seven inches, occasionally more, and has sometimes as many as a dozen keys, seldom less than six; so that every kind of music, however chromatic, within its compass, and adapted to the nature of a tube, may now be executed on this instrument. It is formed of any kind of hard wood, of ivory, and even of glass, and is divided into four joints. The scale of the concert flute is from C below the treble staff to C in the altissimo :—



Some flutes are made to go four notes lower; and an adroit player can reach the E ♭ in altissimo :—



The high notes of the flute are very effective in the orchestra, but its best, its expressive tones, are those between the low C and G in alt, comprising twelve diatonic degrees, and all the intermediate semitones. Performers on the flute, however, like those on most other instruments, strive to astonish rather than please their auditors. Tasteless, senseless execution is all-prevailing, a fact which the great majority of hearers admit, and deplore, while they nevertheless encourage the debasement of one of the most delightful of arts by patiently listening to, and often applauding, that which at best only excites some little wonder, never affords real pleasure, and commonly is the source of dissatisfaction, if not of a feeling nearly allied to disgust.

The OCTAVE FLUTE (called also the *Flauto Piccolo*, *Ottavino*, and *Flautino*, in orchestral scores) is a small instrument an octave higher than the common flute; it is shrill and piercing, and only desirable in the fullest instrumental music, and in military bands. The best of these are provided with four keys.

In the Great Exhibition of 1851, Herr Böhm, of Munich, obtained the approbation of musicians for his improvements of the flute. Mr. J. Clinton's flute is referred to in the Jury Report (Class X. A) as combining the facilities of other modern flutes, and the ordinary system of fingering, at the same time avoiding their defective parts. "In this instrument the tone and time are rendered equal by the same means that M. Böhm has adopted, namely, an equality of size and distance in the holes." It is also said to be comparatively cheap, "the mechanism being so simple that its price does not exceed that of the old eight-keyed flute."

FLUTE-STOP, on the organ, is a range of wooden pipes, tuned in unison with the diapason, and generally proves a most successful imitation of the instrument whence its name is derived.

FLUTE, FLUTINGS. [COLUMN.]

FLUX, in chemistry and metallurgy, is any substance employed to assist the reduction of ores or metallic compounds to their metallic state. In smelting the argillaceous iron ore of this country, which is a mixture of carbonate of iron, alumina, and silica, the flux employed is limestone, in such proportions as will form a slag that melts easily, so as to allow the fused iron to sink through it. When the proportion of limestone has been properly adjusted, the slag has the appearance of green bottle-glass; when, on the other hand, the slag is opaque and blue, it is a sign that a good mixture has not been made.

When copper ores are difficult to melt, fluor spar is added as a flux, which appears to promote the operation.

The fluxes made use of in assays and in chemical operations vary greatly according to the nature of the metal to be reduced and that of the substances combined with it. [ASSAYING.]

We shall mention a few of the more important fluxes employed.

Black flux is made by mixing one part of powdered nitre with two parts of powdered argol, which is the commercial name for impure cream of tartar, or bitartrate of potash: this mixture is to be gradually thrown into a red-hot earthen crucible so as to deflagrate it, taking care not to make the heat so high as to fuse the mixture.

In this case the nitric acid of the nitre is decomposed, its oxygen acts upon the carbon of the tartaric acid, carbonic acid is formed, and this uniting with the potash both of the nitre and bitartrate is converted into carbonate of potash; the whole of the carbon of the tartaric acid is not, however, so acted upon, and the excess remains mixed with the carbonate of potash in the state of finely-divided charcoal. This flux should be immediately reduced to powder and kept in a well-stopped bottle, otherwise it will become damp by the absorption of moisture, to which the carbonate of potash is subject.

This flux is doubly useful; the carbonate of potash combines with the earthy parts of the ore, such as silica and alumina, while the charcoal unites with the oxygen of the metallic oxides, and carbonic acid being formed and expelled, the metal is reduced, and melts. This flux is especially useful in the process of detecting arsenious acid and reducing it to the metallic state.

White flux is a carbonate of potash made by deflagrating equal weights of nitre and bitartrate of potash; the quantity of this last salt being smaller than that in black flux, there is no excess of charcoal furnished by tartaric acid. It appears to possess therefore no advantage over common carbonate of potash, and either of them may be employed in reducing metallic chlorides, such as that of silver, to the metallic state. White flux, or carbonate of potash, disintegrates stony matter, as alumina and silica, separates acids and sulphur from metals, and dissolves many metallic oxides; having, however, no charcoal in its composition, it does not reduce metallic oxides as the *black flux* does.

Argol, already described as an impure bitartrate of potash, powdered and mixed with the pulverised substance to be reduced, is sometimes advantageously used as a flux; owing to the intimate mixture of the charcoal and potash in this flux a good deal of potassium is evolved, and upon the reducing property of this metal the reduction of the oxides of other metals frequently depends to a considerable extent.

Charcoal alone is, in the case of pure oxides, sometimes employed as a flux; thus a crucible lined with charcoal is useful for the reduction of oxide of iron, or the oxide may be mixed with charcoal.

There are some bodies which are even more efficient than charcoal in certain cases, such as wax, fat, oil, tar, and pitch, and gum, sugar, or starch; these may be intimately mixed with the substance to be reduced, and they not only contain carbon in a form which is readily developed, but also hydrogen, which is likely to assist in the separation of the oxygen from metallic oxides.

Flint glass is sometimes, but improperly, used as a flux, for it contains much lead that may greatly interfere with the results produced.

Green bottle-glass has also been used for this purpose, but it is objectionable on account of its containing iron, and it even yields traces of silicon and aluminum to iron which was pure before being heated with it.

FLUXIONS, FLUENTS, METHOD, NOTATION, AND EARLY HISTORY. The method of fluxions assumes a distinct conception of velocity, both in the case of a uniform and variable motion. It further extends this notion of velocity or rate of increase, derived from the consideration of a moving point, to all species of magnitudes, and even to expressions which are purely numerical, as the formulæ of algebra. If one magnitude depend on another for its value, so that a change in the first produces a change in the second, and if the first be imagined to increase at a uniform and given rate, then the second will also increase or decrease, but not at a uniform rate, unless the second magnitude y be determined from the first x by an equation of the first degree, $ax \pm by \pm c = 0$. But the rate at which y increases, though varying with the values of x, can in all cases be determined; and, supposing $\dot{x}$ to be the velocity with which x increases, and $\dot{y}$ that of y, an equation can always be produced of the form

$$\dot{y} = \left\{ \begin{matrix} \text{a function of } x \text{ and } y\text{, depending on} \\ \text{the equation which connects them} \end{matrix} \right\} \times \dot{x}.$$

In this case y and x were called by Newton *flowing* quantities, and $\dot{x}$ and $\dot{y}$ were called their fluxions: conversely y and x were called the *fluents* of $\dot{y}$ and $\dot{x}$. Thus when $y = x^3$ it may be shown that $y = 3x^2\dot{x}$ and if $x = 10$, $\dot{y} = 300\,\dot{x}$, or if the number be increasing continuously, then the increasing number being 10, its cube is increasing 300 times as fast as itself. Thus while a number changes from 10 to 10·01, its cube changes from 1000 to 1003·003001, and 3·003001 is 300·3001 times as great as ·01. That this is not exactly 300 arises from the rate of increase of x^3 not being uniform when that of x is uniform. [VELOCITY.] The velocity of y being variable, may itself be considered as having a rate of change. Thus, if the velocity of a body increase uniformly, the whole velocity gained in a second may be called the velocity of the velocity, or the fluxion of the fluxion. Thus if x increase uniformly, the velocity of $\dot{x}$ is nothing or $(\dot{x})^{\cdot} = 0$, but if $y = x^3$ then $(\dot{y})^{\cdot} = 6x\,\dot{x}^2$. Newton denoted these second fluxions by $\ddot{y}$ and $\ddot{x}$. In a similar way might be determined the velocity of $\ddot{y}$, denoted by $\dddot{y}$, and so on. We cannot find that Newton proposed any symbol for the fluent of a fluxion except the enclosure of its expression; thus,

$$\boxed{3x^2\,x}\ \text{is the fluent of } 3x^2\,\dot{x}\text{, or } x^3.$$

He also in his treatise 'De Quadratura Curvarum,' used z' to stand for the fluent of z.

We now come to the history of this discovery, and of the dispute relative to the right of invention. We have already given a brief outline of the circumstances which led to the publication of the COMMERCIUM EPISTOLICUM, and we shall now add the previous and subsequent occurrences, with some quotations from authorities.

The biographers of Newton state, that about the year 1663 he began to turn his attention to the writings of Descartes and Wallis, and Newton himself testifies that he invented the method of series and fluxions in the year 1665; and that in a tract written in 1666 he had begun partially to use the notation of fluxions. In 1669 Barrow communicated to Collins the tract of Newton, afterwards published under the title of 'De Analysi per Equationes numero terminorum infinitas;' of which he afterwards says, "I am glad my friend's paper gives you so much satisfaction: his name is Mr. Newton, a fellow of our college, and very young (being but the second year Master of Arts), but of an extraordinary genius and proficiency in these things." This tract contains a method of series, and many problems solved by application of limits to differences obtained by expansion; but no direct method of fluxions. It was first published by William Jones, who had become the possessor of Collins's papers, in 1711, in a tract which is little known, having been superseded in the following year by the publication of the Commercium Epistolicum. Various letters of Newton, Collins, and others, up to the beginning of 1676, state that the first-named had invented a method by which tangents could be drawn, &c., without the necessity of freeing their equations from irrational terms. Among them is a letter from Newton to Collins, dated December 10, 1672, in which he states the fact of his discovery, with one example. This letter the committee [Commercium Epistolicum] assert to have been sent to Leibnitz, but without proof: and it has been since ascertained that nothing but an imperfect extract was sent to Leibnitz. Leibnitz desired to have this method communicated to him; and Newton, at the request of Oldenburg and Collins, wrote to the former the celebrated letters of June 13 and August 24, 1676. In the first he states the binomial theorem, and various consequences of it in combination with his method, but without giving any information as to that method. Leibnitz in a reply, also addressed to Oldenburg, speaks in the highest terms of what Newton had sent, and requests further explanation. Newton, in the second letter just mentioned, then explained how he arrived at the binomial theorem [Binomial Theorem], and gives various results of his method. He also communicated his method of fluxions and fluents *in cipher* (as was often practised at the time), if cipher it could be called, which had no method by which it could be deciphered. It consisted in placing in alphabetical order all the letters in the sentence communicated. Thus Newton gravely tells Oldenburg that his method of drawing tangents was

6 accdæ 13 eff 7 i 3 l 9 n 4 o 4 qrr 4 s 9 t 12 vx;

or, that if any one could arrange six *a s*, two *c s*, one *d*, &c., into a certain sentence, he would see the method. That sentence was, Data Æquatione quotcunque fluentes quantitates involvente fluxiones invenire, et vice versa. If Leibnitz could have taken a hint either from the preceding letters in alphabetical order, or (had he known it) in their significant arrangement, he would have deserved as much credit for his sagacity, as if he had made the invention independently. We cannot find anything in the rest of the letter which could give any such hint; and certainly Newton, who showed himself desirous to conceal the method, and knew that his letter was to come under the acute eye of Leibnitz, did not imagine that he had in any part of it betrayed his secret. This letter, of October 24, 1676, had not been sent to Leibnitz, March 5, 1677, as Collins informs Newton by letter of that date. So early as June 21, of the same year, however, Leibnitz had received that letter and written an answer to Collins, in which, without any desire of concealment, he explains the principle, notation, and use of his differential calculus: this letter was published in the 'Commercium Epistolicum.' It is of this correspondence that Newton wrote the celebrated scholium; of which, as we shall see, he was afterwards weak enough, first to deny the plain and obvious meaning, and secondly, to omit it entirely from the third edition of the 'Principia.' This scholium, very literally translated, is as follows (book ii. prop. 7, scholium).

A.D. 1687. "In letters which went between me and that most excellent geometer, G. G. Leibnitz, ten years ago, when I signified that I was in the knowledge of a method of determining maxima and minima, of drawing tangents, and the like, and when I concealed it in transposed letters involving this sentence (Data æquatione, &c., above cited), that most distinguished man wrote back that he had also fallen upon a method of the same kind, and communicated his method, which hardly differed from mine, except in his forms of words and symbols."

It will be convenient here to give Newton's subsequent explanation, given in the year 1716, taken from his remarks on Leibnitz's letter to Conti of April 9, 1716, published in 1716 in the appendix to Raphson's 'History of Fluxions.'

"He pretends that in my book of principles I allowed him the invention of the calculus differentialis, independently of my own: and that to attribute this invention to myself is contrary to my knowledge there avowed. But in the paragraph there referred unto I do not find one word to this purpose. On the contrary, I there represent that I sent notice of my method to Mr. Leibnitz before he sent notice of his method to me: and left him to make it appear that he had found his method before the date of my letter; that is, eight months[*] at the least before the date of his own. And, by referring to the letters which passed between Mr. Leibnitz and me ten years before, I left the reader to consult those letters[*] and interpret the paragraph thereby. For by those letters he would see that I wrote a tract on that method and the method of series together, five years before the writing of these letters; that is, in the year 1671. And these hints were as much as was proper in that short paragraph, it being beside the design of that book to enter into disputes about these matters."

Nothing material passed till 1684, in which Leibnitz gave his first paper on the Differential Calculus in the Leipzig Acts. In 1687 the 'Principia' was published by Newton; and Leibnitz continued to give papers on the subject of his new calculus. The Bernoullis began to cultivate the subject about the year 1691, and as they were on terms of correspondence with Leibnitz, he was the source from whence they drew, and to which they returned, additional ideas on the subject. The Marquis de l'Hôpital was employed in writing his elementary treatise (the first written), which was published in 1696. All these considered Leibnitz as their chief; and the consequence was that Dr. Wallis informs Newton, by letter of April 10, 1695, that "he had heard that his notions of fluxions passed in Holland with great applause by the name of Leibnitz's Calculus Differentialis." Accordingly, Wallis, who had just completed printing the first volume of his works (the third, which contains Newton's letters to Oldenburg, having been previously printed), inserted in the preface, as a reason for not mentioning the differential calculus, that it was Newton's method of fluxions which had been communicated to Leibnitz in the Oldenburg Letters. A review of Wallis's works, in the 'Acta Eruditorum, or Leipzig Acts,' for 1696, reminds the reader of Newton's own admission above cited. On this Newton (Raphson, supplement above cited) remarks, "Whether Mr. Leibnitz invented it after me, or had it from me, is a question of no consequence, for second inventors have no right."

In 1699 Fatio de Duillier, a Genevese, settled in England, stated in a mathematical work his conviction that Newton was the first inventor, adding that he left it to those who had seen the manuscripts and letters to say whether Leibnitz borrowed from Newton. This was the first distinct suspicion of plagiarism; and Leibnitz, who had never contested the priority of Newton's discovery, and who appeared to be quite satisfied by Newton's admission, now appears for the first time in the controversy. In a reply to Duillier (Leipzig Acts, 1700), after calling attention to Newton's scholium, he declares that when he published his method, in 1684, he knew nothing more of any method of Newton, except that the latter had written to him that he could dispense with the removal of irrational terms; and that, though on the publication of the 'Principia' he became aware how much further its author had pushed his discoveries, he did not know that Newton possessed a *calculus* (or organised method) like the differential, till the publication of Wallis's preface.

The 'Quadrature of Curves' was published by Newton in 1704, at the end of his 'Optics.' It contains a formal exposition (the first published) of the method and notation of fluxions. Some propositions had been already published by Wallis. But in all that Newton had previously allowed to be published, as well as in his early papers which have been published in our own time, he uses the language and ideas of *infinitely small quantities*. These he now rejects.

Since so great a stress was laid by the parties to the quarrel on the introduction of specific notation, we may remark that Newton himself did not very soon adopt such a course. He says that in 1666 he "sometimes used a letter with one prick for quantities involving first fluxions; and the same quantity with two pricks for quantities involving second fluxions." Even so late as 1687 he does not (in the 'Principia') give any notation for the *momenta* to which he had given a name, and (though not laying any stress on it) we doubt whether Newton would ever have systematised his notation if he had not seen the letter of Leibnitz referred to in the scholium.

A review of the above work appeared in the 'Leipzig Acts,' January, 1705, in which, after stating that the differential calculus had been explained in that work by Leibnitz, its inventor, and further by the Bernoullis, and De l'Hôpital, the author proceeds as follows: "Instead of the Leibnitian differences Newton applies and always has applied (adhibet semperque adhibuit) fluxions, which are *quam proximè* as the increments of flowing quantities generated in infinitely small times, and has used them with elegance both in his 'Principia' and in subsequent writings, just as (quemadmodum et) Fabri in his synopsis has substituted (substituit) motion for the method of Cavalieri." This was considered by Newton's friends as an imputation of plagiarism on their chief; but such a construction was always strenuously resisted by Leibnitz. On the one hand, it was declared that Newton was represented in the same light with regard to Leibnitz as Fabri to Cavalieri, by the force of "quemadmodum et;" on the other, it was replied that the distinction between separate invention and borrowing was preserved in *adhibuit* and *substituit*. We are inclined to suspect that the meaning of the writer was not very fair, though the words *semperque adhibuit* are rather in his favour. Be this as it may, the preceding sentence called forth the assertion of Keill ('Phil. Trans.,' 1708), that

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[*] He must have known by Collins's letter that it was not three.

[*] They had not then been published, nor was it known that they were to be published.

Leibnitz had inserted Newton's method, changing its name and notation in the Leipzig Acts. The article COMMERCIUM EPISTOLICUM takes up the history at this point.

The 'Commercium Epistolicum' did not reach Leibnitz, who was at Vienna, for a considerable time. In the mean while he wrote to John Bernoulli (who had received his copy) for his opinion of the work. This the latter gave, first in a letter to Leibnitz, and afterwards (as Leibnitz asserts) in an anonymous tract published in July, 1713. But, as in this tract the author speaks in complimentary terms of John Bernoulli, it has been supposed that at least it was edited by some one else. This letter is decidedly as unfair towards Newton as the friends of the latter had been towards Leibnitz; it asserts the method of fluxions to be a plagiarism from the Differential Calculus. Keill printed a reply, and Newton and Leibnitz then appear as mutual accusers, in letters to Mr. Chamberlayne. Nothing remarkable arose out of this correspondence, which terminated in the announcement of Leibnitz that he also would prepare a 'Commercium Epistolicum.' About December, 1715, Leibnitz re-opened the matter in a letter to the Abbé Antonio Conti of Venice, then on a visit to England. He there complains of the treatment he had received, and attacks the Newtonian philosophy in general. Newton wrote a reply, February 26, 1715–16, in which he very much dwells on previous admissions made by Leibnitz. The latter, in a third letter to Conti, April 9, 1716, avows that he always believed Newton upon his word, but that, seeing him connive at accusations which he must have known to be false, it was natural that he (Leibnitz) should begin to doubt. Newton is also reminded that he had made some admissions in favour of Leibnitz (in the scholium) which he was now desirous of disavowing. This letter was not sent directly to Conti, but first to Paris, that it might be there seen and copied by a friend: on which Newton refused to send any answer, considering it as an insult that Leibnitz, though he complained of suppressions in the 'Commercium Epistolicum,' should take means to preserve evidence to the whole of his letters. But Newton circulated some remarks among his friends, which he published immediately on hearing of the death of Leibnitz, November 14, 1716. It is in this last paper that the remarkable sentence occurs which we have quoted above in connection with the scholium which it disavows. Raphson's 'History of Fluxions' being then ready for publication (its title-page bears 1715), or perhaps published, the Conti correspondence was annexed as a supplement.

The history of the controversy ends with the death of Leibnitz, and we shall conclude this article with a few additional quotations and facts which bear upon the subject.

1. The second letter of Keill (May 24, 1711) [COMMERCIUM EPISTOLICUM], on which the whole of the subsequent dispute arose, was in substance the statement of Newton himself. In the minutes of the Royal Society, April 5, 1711, it is stated that "the president gave a short account of the matter, with the particular time of his first mentioning or discovering his invention, referring to some letters published by Dr. Wallis: upon which Mr. Keill was desired to draw up an account of the matter in dispute, and set it in a just light." The letter in question was the consequence, which was read at the meeting of the 24th of May (its date).

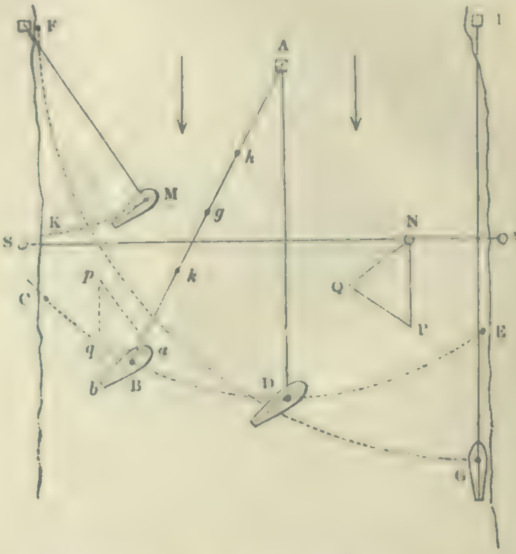
2. The original committee consisted of Dr. Arbuthnot, Mr. Hill, Dr. Halley, Mr. Jones, Mr. Machin, and Mr. Burnet. This is what Newton has been supposed to call "a numerous committee of gentlemen *of several nations*:" and singularly enough, no writer on the other side has ever noted this apparent unfairness. But it has lately been discovered that Newton was right. During the investigation there were added to the committee, Robarts, Aston, Brook Taylor, *Bonet*, the Prussian minister, and *De Moivre*. The names of the committee were not published with the 'Commercium Epistolicum.'

3. So far from the committee considering themselves as in any judicial capacity, it appears, from a letter of Burnet above-named to John Bernoulli (which the latter sent to Leibnitz, and the extract is in the published correspondence of the two), that the Royal Society was busy proving by original letters that Leibnitz might have seen the method of fluxions in the correspondence of Oldenburg, &c.

There was throughout the whole dispute a confusion between the knowledge of fluxions or differentials and that of a *calculus* of fluxions or differentials, that is, a digested method with general rules. If the dispute could be revived at the present time, it would be on entirely different grounds: but of course, in describing the controversy as it existed, we need only consider those points which were put in issue by the parties themselves.

FLYING BRIDGE. This consists usually of a boat or other vessel which, being attached by a rope to a buoy, moored in the middle of a river, is made, by the action of the current, to move across on an arc of a circle of which the buoy is the centre. On large rivers, at places where the communications across them are very frequent, such bridges will probably, in future, be superseded by steam-vessels; but, for temporary purposes, and particularly to facilitate military operations in countries where steam navigation is not in use, they may be of the highest importance.

Let A be a buoy securely anchored in the middle of a river, and B a boat to which, at a point about one-third of the vessel's length from the head, is attached one end of the cable or chain B A: then $p\,b$ indicating the direction of the current, if the keel $a\,b$ of the boat be inclined to that direction in any angle as $p\,b\,a$, the pressure of the water against one side of the boat being resolved in a direction $q\,a$ perpendicular to $p\,b$, or across the river, will cause the boat to describe the arc C D E, whose centre is A. As far as the point D, in the middle of the river, the boat descends, but afterwards it ascends obliquely against the current; for while its keel is kept by the rudder in a position nearly parallel to $b\,a$, the force parallel to $q\,a$ continues to act and impel the boat towards E. If f represent the direct force of the current, and θ the angle $p\,b\,a$, the force perpendicular to $p\,b$ will be expressed by $f \sin^2\theta \cos\theta$; and this will be a maximum when $\theta = 54^\circ 44'$. It is evident that by increasing the length of the rope A B, the length of the arc between C and E will be diminished; the retardation arising from the action of the current, in ascending from the middle of the river to E, will also be less: the length of the rope or chain should, in fact, be such that the arc C D E may not exceed a quarter of the circumference of the circle; and when, for this purpose, the length is very great, it must be supported as at g, h, and k, on moveable buoys or small boats.



A flying bridge sometimes consists of a simple flat-bottomed vessel, having a mast fixed to one of its sides in the middle of its length. The cable passes through a block at the mast head, and is attached at one end to the opposite side of the vessel, the other end being made fast to the buoy. Two ropes connected with the cable lead one to the head and the other to the stern of the vessel; and, by pulling on one of these, the other being let go, the vessel is placed in a position oblique to the current: this position is retained by means of a steering oar aided by a current-board which may be let down into the water at the head or stern as the case may require.

In a rapid current it may be impossible to make the boat B move up the ascending arc D E; in which case a boat at F, by means of a cable made fast at H on the opposite bank, may be allowed to describe the descending arc F G. On setting out from F, the boat takes with her a coil of rope, of which one end is attached to a fixed object near that place; then, on arriving at G, the boat is drawn up along the bank to H; and by the rope is hauled across the river to F, from whence it set out. Again, a rope being made fast to an object near F, a boat may be steered obliquely from some point as K, till she comes to a part, as M, of the river at which the current acts strongly upon her; then letting go the rope and, by the rudder or steering oar, keeping the boat's keel at a proper inclination to the direction of the current, the resolved force of the water will impel the boat to some point, as G, on the opposite bank.

When the river is too wide for a boat to swing over in a single arc, two buoys may be moored in a direction across the river, at equal distances from the banks and from each other, and two boats connected with them by ropes may be impelled in circular arcs, one extending over the first half of the breadth of the river, and the other over the second: a raft being moored in the middle facilitates the transference of the passengers, &c., from one boat to the other; or, without the raft, one boat, on arriving in the middle of the river, may transfer its passengers immediately to that which is to describe the other half of the breadth.

A triangular raft N P Q having its front, as N P, parallel to the direction of the current, and being connected by a ring at N, with a rope S V stretched tightly across the river, may, by a resolved force of the current on N Q, be impelled directly to the opposite bank; and, on reversing its position so that P may be connected by a ring with the rope S V, the raft may be impelled across in a contrary direction. A boat running by a ring at one end, on S V, may, by being kept in a position corresponding to that of the line N Q, in like manner be *sheered* across the river.

On broad rivers, and when objects of great bulk and weight, as horses, carriages, or artillery, are to be conveyed across, two boats or barges placed in parallel positions, and carrying a platform extending between their exterior gunwales, are employed: the bay or interval between the vessels is as wide as is consistent with the strength of the platform, in order that as much as possible of the current may act against a side of the lower vessel. The vessels are made narrow and deep, and each is provided with a mast, which may be from twenty to thirty feet in height; these are connected together at ten or fifteen feet from the platform by two horizontal beams, one above the other, and between them is a block of wood which is capable of sliding from one mast to the other. The cable or chain is made to pass through a perforation in the sliding piece, and the latter is placed contiguously to either mast, according to the direction in which the vessels are to move. A drawbridge is constructed on each side of the platform, and one of them is let down to form a passage when the vessels arrive at the landing-place on either side of the river. Each vessel has a rudder, and the tillers are connected by a bar, in order that one man may be able to turn both.

For ample details concerning the subject of this article, see Sir Howard Douglas on 'Military Bridges.'

FLYING SAP, is the sap formed by placing and filling several gabions at the same time, and not in succession as in the usual method employed in making the second parallel in the attack of a fortress.

FO, pronounced by the Chinese Fŭh, is the name by which Buddha is worshipped in China. According to the Chinese authorities quoted in Dr. Morrison's 'Chinese Dictionary' (vol. i. part i. pp. 92, 93), the religion of Fo was introduced into China in the seventh year of the reign of the Emperor Ming, about A.D. 50. Though the Chinese government has usually discountenanced, and at some periods persecuted, the followers of Fo, they have always been very numerous; yet Sir J. F. Davis remarks, in his work on the Chinese (vol. ii. p. 94), that, "the present condition in China of the religion of Fŏ is very far from flourishing; and the extensive and magnificent establishments which have been founded in former times are evidently in a state of dilapidation and decay. It is rarely that one meets with any of their nine or seven-storied pagodas in tolerable repair, though one or two of these striking and elegant objects occur in almost every landscape. Between Macao and Canton there are no less than four or five nine-storied pagodas on elevated points by the river-side, and every one of them is in a state of ruin." [Buddha.]

FOCUS, Geometry. [Ellipse; Hyperbola; Parabola.]

FOCUS, a Latin word signifying a *hearth* or *fire-place*, used in optics to denote the point at or near which the rays of light are collected by a lens or mirror. Its distance from the lens or mirror is called the *focal length*. [Lens; Mirror.]

FOG. [Mist.]

FOG SIGNALS. The blowing of a horn, the ringing of a bell, the beating of a drum or gong or empty cask, the firing of a gun,—in short, any uncouth noise made on board a ship to warn others of her presence, is in a fog a means of safety. The Admiralty have rules for the government of a fleet of men of war in thick weather, such as occasional firing or ringing of a bell to indicate what tack a ship is upon, &c.; but little has been done for single ships of the merchant service on this important subject beyond certain regulations for the use of light-houses and light-vessels, although every provision was made in the Merchant Shipping Act of 1854, for the enforcing of such regulations as might issue from authority. Difficulties evidently beset the question, as the safe passage of a ship in foggy weather through our crowded maritime highways must depend so much on individual precaution.

As the principal commerce of the kingdom is becoming more and more carried on by steamers, and their "whistles" are a powerful and characteristic mode of warning, it might be well to organise a few signals for general use, after the following manner.

Let the mark "—" represent, on paper, a sound from the steam whistle, lasting while a person could leisurely count *four*, and the mark "⌣" indicate another sound from the whistle, enduring while a person could leisurely count *two*.

It being in a fog so important to know *in what direction a steamer is coming or proceeding*, the following eight signals would form a complete code, which might moreover, from their extreme simplicity, be used either in a dark night or in hazy weather at any time.

If a vessel is standing towards the North, let her course be represented by . . } —
If North-East " " . . — ⌣ ⌣
If North-West " " . . . ⌣ — ⌣
If East " " . . ⌣ ⌣
If South " " . . . ⌣ —
If South-East " " . . ⌣ ⌣ —
If South-West " " . . . — — ⌣
If West " " . . — ⌣

As every sailing-vessel is supposed to carry a "fog horn," the above signals so easily made on it, or on a bugle, or with a common whistle, or even with the mouth (on an emergency), would in many cases probably prevent collision [Collisions at Sea]. And further, if a vessel be on the starboard tack, close hauled, a prolonged blow would announce it, and if close hauled on the port tack, a few short repeated sounds of any sort would give sufficient notice: while a vessel at anchor might make any *beating* sound.

But all precautions taken on board ship in certain cases will prove useless unless means be taken to give sounds from the shore. The humane but partial and voluntary custom in some parts, of ringing a village church bell on a coast in thick weather, if rendered compulsory, —or the sounding of a bell at certain conveniently situated coast-guard stations along the shore,—would not only alleviate the dangers which at present threaten seamen, but it would be a boon to boatmen and fishermen. For instance, three long sounds of equal length might always be used to indicate *the shore*.

An excellent fog-horn has recently been introduced from the United States.

Fog-signals, made with an explosive material, are also used on railroads. They are placed on the rail; the engine-wheel on passing over it causes it to explode with a noise calculated to announce the approach of the train to a considerable distance.

FOIL, is a very thin sheet of metal, made usually for placing beneath artificial gems to heighten their brilliancy. Foils are made of tin, copper, tinned copper, or silvered copper—the last for the best work. They are left white for imitative diamonds, but are coloured for imitative rubies, sapphires, &c. The best white foil is made by coating a plate of copper with a layer of silver, and then rolling it into sheets in the flatting mill. The coloured foils are prepared by coating the white foil with coloured varnish. The principal colours used by artists are employed, mixed with mastic, spirit, and drying oil, to form the coloured varnishes. The following are examples:—amethyst foil, lake and Prussian blue finely ground in drying oil; sapphire foil, Prussian blue and drying oil; garnet foil, dragon's blood and rectified spirit; emerald foil, pale shellac, alcohol, and acetate of copper; ruby foil, lake, isinglass, and shellac; topaz foil, turmeric, annatto, and shellac.

Sheet lead, so extremely thin as to resemble foil, is employed as a lining for tea-chests. Mr. Wimshurst, one of the managers of the Assam Tea Company, invented, in 1858, a very peculiar method of producing this foil. It is said that England sells no less than 4000 tons of lead annually to the Chinese, chiefly to be made up into foil for lining their tea-chests; this they do rather clumsily. The Assam Company paid from 2000*l*. to 3000*l*. a year for lead-foil made on the old method of rolling; but Mr. Wimshurst has effected a great saving in this item by the adoption of his new method. He makes a cylinder of lead, by casting in a mould having a mandril or core in the centre; the mould opens by a hinge into two halves, and liberates the metal. A knife or cutter, as long as the cylinder, is gradually brought up to it, and shaves the surface. The cylinder rotates slowly while being thus cut. The mechanical arrangement is such that the cutting-blade advances gradually towards the axis of the cylinder, and the rate of this advance determines the thickness of the film. The film is received on a collecting spindle, which can be removed with the coil upon it. The cutting-machine acts equally well on a cylinder of tin or one of lead, or of a combination of the two metals.

FOLK-MOTE, or FOLK-GEMOTE, literally a meeting of the people; an assembly under the Anglo-Saxon government, respecting the nature of which some of our antiquaries have differed. Sir F. Palgrave believes that it existed in Britain before the establishment of the Saxons. Somner, in his 'Anglo-Saxon Dictionary,' calls it a general assembly of the people for considering and ordering matters of the Commonwealth. So the laws of King Edward the Confessor, "Folcmote, *i.e.*, vocatio et congregatio populorum et gentium omnium, quia ibi omnes convenire debent, et universi qui sub protectione et pace Domini Regis degunt." The continuation of this statute of Edward the Confessor expressly directs that the meeting of the Folcmote should be held once in the year upon the 1st of May. "Statutum est enim quod ibi debent populi omnes, &c., semel in anno scilicet convenire, scilicet in capite Kal. Maii." (Wilk., 'Leg. Anglo-Sax.,' p. 204.)

Brady, in his 'Introduction to Old English History,' Gloss. p. 47, is entirely mistaken when he speaks of it as an inferior ordinary court, held once a month. This was the Hundred Court. The Folk-mote and Shire-mote (or general meeting of a county) were synonymous. (Wilk. ut supr. Gloss. p. 404.) According to Sir F. Palgrave, the Folk-mote was a representative assembly to which the various districts sent their sheriff (gerefa) and four men. It certainly possessed judicial powers, of which he gives examples ('Rise and Progress of the English Commonwealth'); and jurors appear in many instances to have been selected from among the representatives attending the Folk-mote. The Folk-mote, indeed, appears to have had nearly the same constitution, with powers, limited by the locality it represented, as the Witenagemote; to which frequently the same representatives were sent as attended the Folk-mote.

In later times a Folk-mote, according to Stow, among the citizens of London, meant a meeting of themselves. Fabyan, in his 'Chronicles' (edit. 1811, p. 344), mentions a court of folk-mote held at Paul's Cross in 1256; and another assembled by command of Henry III. (ibid. p. 345), "where the king, according to the former ordinances made, axed licence of the commonalty of the city to pass the sea."

FOMENTATIONS are liquid applications, generally of a warm temperature, placed in contact with a limited portion of the body, to mitigate or remove disease of the part, or of the neighbouring organs. They differ from partial or local baths, chiefly in the greater length of time which they are kept applied. Flannel cloths, or other substances, such as the spongio-piline, fit to retain heat and moisture, are commonly employed. To enable these substances to retain the heat still longer, they are often covered externally with oiled silk. It is proper to renew the application before the cloths begin to give a feeling of coldness. The liquids used are of various kinds, sometimes pure water; at other times medicated; they are termed emollient when charged with mucilaginous principles, such as mallows, and sedative or anodyne when they contain a narcotic principle, such as poppy heads.

FONT, the vessel placed in a church to contain the water employed in baptism. The form of the font is evidently derived from that of the larger Roman stone vases, but few if any of the fonts now found in churches are of a date earlier than what in architecture is known as the Romanesque period. In our own country there are a great many fonts, curious both for their antiquity and their architectural design. One or two are, on questionable grounds, attributed to the Saxon period; but those respecting which there is no difference of opinion range from the Norman period to the decline of Gothic architecture.

What may be called the normal form of a font is that of a cup or bowl hollowed out for water, and supported on a thick solid stem. The exterior of the bowl is in the older examples round, or square, but in the later most commonly octagonal; and the sides and stem are often highly enriched with sculptured figures, and occasionally traces of colour and gilding still remain, as at Gorleston and Blythborough, Suffolk, and Gresham, Norfolk. In many instances, a flight of steps forms a base for the stem; and in fonts of the Perpendicular period, even the steps are carved with panels, having quatrefoils and rosettes sunk within them. From about the middle of the 13th century, when by a rescript of the Archbishop of Canterbury fonts were required to be covered and locked, the lids of fonts began to acquire an ornamental character equally with the fonts themselves. At first they were merely plain covers with padlocks, but eventually (though probably not before the middle of the 15th century) they assumed a pyramidal or spire-like form, richly carved with a profusion of shafts, buttresses, and tracery, piled up to the apex. Covers of this kind still remain at Castleacre and North Walsingham churches, Norfolk; Ewelme, Oxfordshire; Thaxted, Essex, and elsewhere.

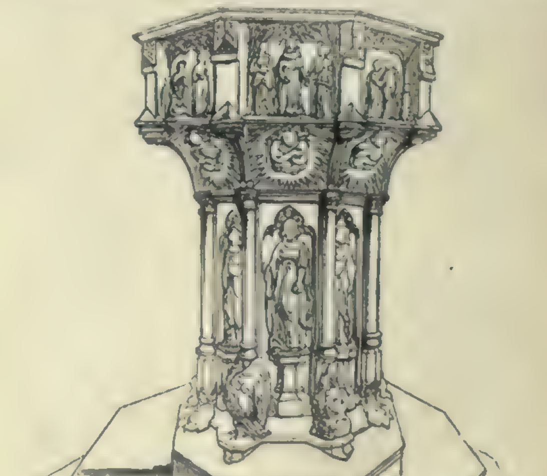
The more ancient fonts are generally very large; the basin being sufficiently capacious to permit of the baptism of the infant by immersion. As a rule they are made of stone, and almost always from a single block; but some leaden fonts of Norman, as well as of later date, are still extant both in this country and in France: in the latter country a few remain of copper or bronze. Fonts were mostly placed in the western end of the nave, near the entrance of the church; but sometimes in a portion of the church separated from the body of the building by walls or a screen, or entirely detached from it. Of these baptisteries as they were called [BAPTISTERY], examples occur at Canterbury Cathedral; Luton, Bedfordshire; Cranbrook, Kent; and Menacuddle, St. Austel, Cornwall; but more perfect examples may be found in some recent churches erected in conformity with strict "ecclesiological" principles; as All Saints, Margaret-street, London, where the font (which has a carved cover of the kind described above), is enclosed in a rich baptistery, which is shut off from the nave by low walls, though under the same roof; and at All Souls' church, Halifax, where a baptistery is formed in the basement of the tower, which stands at the north-west angle of the church.

Fonts of Norman date are nearly always large and massive; the basin is usually round or square, but some occur which have been rendered octagonal by chamfering off the angles of the square blocks, as at Drayton church, Norfolk. They are supported on a very thick stem, but in some of the largest there are also smaller shafts placed under the angles of the basin, as at Lincoln cathedral; Ifley church, Oxfordshire; South church, Hayling Island, Hampshire, &c. Norman fonts are frequently sculptured with rude bassi-relievi, of the Crucifixion or Baptism of Christ, or some other typical subject, figures of the apostles, saints, grotesque figures, scroll-work, &c. Porchester church, Hants, has a very ancient circular font, resembling in character the puteal, or circular stone-mouth of the well in the atrium of a Roman house: it is decorated with intersecting arches on columns, with a frieze of foliage and figures above. At Coleshill, Warwickshire, is a Norman font, of which the basin is a mere cylinder, but elaborately sculptured outside with the Crucifixion (enclosed within a circle), the evangelists, &c., and supported on an enormously thick stem. A handsome circular font richly covered with scroll-work occurs at Great Shefford church, Berks; at Monks Risborough, Buckinghamshire, the circular basin is fluted. Most Norman fonts are of stone, but some occur of lead. One of the most remarkable of these is in Dorchester church, Oxon. The bowl is of cast lead, of 1 foot 10½ inches internal diameter, 2 feet 2 inches external, and 1 foot deep. Around the outside are eleven seated figures under semicircular arches, representing, probably, the Apostles—Judas being omitted. The pedestal is of stone and more modern. A leaden font of very beautiful workmanship is in the chapel of Llancourt, on the Wye. Fonts of the same date in Normandy, are almost exactly similar in style, but somewhat richer and more refined in finish; showing, not merely similarity of origin, but supporting the probability of their being executed by the same workmen, or workmen trained in the same school.

Fonts of the First Pointed, or Early English date, are like those of the preceding period, circular and square, but they are likewise not seldom octagonal. In general character they greatly resemble the Norman, but they differ from them in being somewhat less massive, and more finished in style; they have sometimes arcaded-work, sometimes trefoils on the bowls, with slender shafts dividing the panels, and almost always detached supporting shafting, as well as a thick central stem.

In the Second Pointed, or Decorated Style, the fonts are finer in design than the earlier examples, but less refined in execution than might be expected from the superiority of the buildings of this period. The basins are now usually octagonal, but occasionally they are hexagonal, as at Rolvenden, Kent, and Drayton Parsloe, Buckinghamshire. Fonts of this period are characterised by the flowing tracery of the panels, engaged shafts, highly enriched ornamentation, diapered panels, and occasionally elegant sculpture. A good example of this style occurs in the church of All Saints, Norwich.

In the Perpendicular, or Third Pointed Style, the form is almost invariably octagonal. Occasionally figures of men or animals are introduced as apparent supporters to the bowl, as at St. Martin's, Oxford, where supporting figures are placed within recesses formed by buttresses at the angles of the stem; and at St. John's, Norwich, where lions are similarly placed. The ornamentation is now much more rich, becoming more and more florid in the later examples, and at last erring greatly on the side of excess of decoration, as in the otherwise fine font at Walsoken, Norfolk. On the panels of the basin foliated circles or quatrefoils frequently inclose roses or heraldic shields. The stem, where single, is often octagonal and panelled. Statuettes and bassi-relievi, sometimes very beautifully executed, occur in the costlier examples, both within niches on the panels of the basin, and around the stem. A very beautiful example of a Perpendicular font of the best period occurs at East Dereham Church, Norfolk, of which we give an engraving. The lofty pyramidal font-covers spoken of above, are chiefly of this period—the famous one at Ewelme, Oxford, which is 10 feet 6 inches high, is a characteristic example.



Font in East Dereham Church, Norfolk, from an original drawing made by Mr. W. B. Clarke, architect, in 1834.

From the decline of Gothic architecture little attention was given to fonts in this country; and not only were no new ones of any artistic pretension executed, but the old ones were neglected, and often applied to the most unworthy uses. Since the revival of Gothic architecture, however, many fonts have been executed of a very costly kind, and exhibiting great imitative skill, if not much originality of design.

Simpson's 'Series of Baptismal Fonts,' and Paley's 'Illustrations of Baptismal Fonts,' furnish descriptions and engravings of numerous English fonts of the several periods, and the latter work gives also careful admeasurements of each example: the 'Archæologia,' the 'Archæological Journals,' and the local histories, will supply many additional instances. Sufficient examples and descriptions (for the purpose of comparison) of French fonts, will probably be found in M. A. De Caumont's 'Cours d'Antiquités Monumental,' vol. vi., and 'Atlas,' Paris, 1841; and his 'Rudiment d'Archéologie—Architecture religieuse,' Par. 1854.

FOOD. All organised bodies are nourished by he introduction into their internal structures of materials from without. Such materials are called indifferently aliments or food, and are fitted to supply and maintain the fluid and solid matter of the body. For this purpose they must either be soluble naturally, out of the body in common menstrua such as water, or capable of being dissolved by the digestive principle of the stomach. However diversified the articles employed may be in external appearance or chemical composition, they are reduced by the action of the organs of digestion into a fluid (chyle) [DIGESTION, in NAT. HIST. DIV.] of homogeneous character, which is reconverted into solids and fluids of different natures by the influence of the powers of assimilation. Before undergoing this second change, they must be brought into the state of arterial blood, and so form a part of the circulating fluids of the body. Substances which are incapable of undergoing these successive changes cannot be considered as articles of food, or capable of imparting nourishment to the frame. There are however various articles which, although incapable by themselves of nourishing, appear, when taken in conjunction with other articles, to contribute essentially to nutrition. But even of a substance unquestionably nutritious, the whole mass is never completely nutritive, that is, capable of being entirely assimilated; some portion of it merely giving it bulk, or being of a nature calculated to make certain impressions on the organs of digestion, and to stimulate them to those actions which conduce to the exercise of the function of digestion, such as the *tannin* of our vegetable food, salt and other condiments.

Those substances which have previously been endowed with life can alone be considered as affording nutriment to animals of a high degree of organisation, such as man, of whose aliment we here mean to treat. For a practical view of the subject, it may be divided into two heads, namely, the substantials and the accessories; the first comprising the real materials or sources of nourishment; the second, condiments, &c., which either render the food more grateful to the palate, or by a vital or chemical action on the organs of taste and the stomach, promote its digestion.

It is customary to distinguish the articles of food into solid and fluid, or meats and drinks, and into animal and vegetable. But the former is merely a distinction of convenience, and does not extend to any ultimate difference in the nature of the material, but only to the manner in which they are respectively treated by the organs of digestion; while the latter is only important in a medical point of view, as relates to the amount of nutriment in a given quantity of food, and the impression which the two kinds of food make upon the system generally. "Specific differences are distinguishable in the chyme at least, if not in the chyle, according as the food from which it is formed has consisted of vegetable or animal matter, and according as it has contained fatty or oily substances, or been destitute of them." Nevertheless as those substances alone contribute to the nourishment of the body by being assimilated by it which can be resolved into *their organic molecules*, and as these are only found in the proximate principles of animals and vegetables, of which principles none perhaps are exclusively animal, it seems most advantageous to treat at the outset of the principles, without reference to the source whence derived. The molecules can only be liberated by being diffused through some fluid, and therefore it matters not whether they be brought into such a condition by external agency or by the apparatus with which the higher animals are furnished, namely, the teeth, stomach, &c. To a fluid state they must be brought before they can pass the fine strainers of the alimentary canal. The resolution of the materials of food into their organic molecules is the real office of the digestive organs, while exercising that function within healthy limits; the resolution of the proximate principles into their elementary or ultimate principles, when various gases are evolved, is a morbid or diseased action of these organs.

The proximate principles of alimentary substances consist sometimes of three, sometimes of four elementary or constituent principles. Those which consist of three are of most frequent occurrence in the vegetable kingdom; those which consist of four are of most frequent occurrence in the animal kingdom. Where the elements are three only they are generally oxygen, hydrogen, and carbon; where four, oxygen, hydrogen, carbon, and nitrogen, or azote. The predominance of carbon is the characteristic of vegetable matter; the predominance of nitrogen the characteristic of animal matter. Wherever nitrogen is absent in animal matters the substance approximates, or is analogous to, vegetable matter, such as animal fats, which closely resemble vegetable oils. Animals which are decidedly carnivorous do not prosper if kept long on food destitute of azote; but man, whose dwelling-place is under different climates, can dispense with an azotised diet better in some parts of the world than in others, for instance, better in tropical countries than near the poles. The pilgrims and attendants on the caravans in their journeys across the deserts of Africa can subsist for a length of time on gum, which does not contain azote. Majendie, who carefully investigated the subject, concludes from his experiments—1st, That animals derive the azote which enters into their composition entirely from their food, and hence, that no animal can live for a considerable time on food entirely destitute of azote. 2nd, That animals, even those naturally carnivorous, can live a certain time upon food entirely destitute of azote, in consequence of which the excretions of those naturally carnivorous become altered, throwing off less azote than when they are fed on animal food, and acquiring the properties which these excretions have in animals whose food contains a very small proportion of azote. 3rd, That vegetable and animal substances destitute of azote are highly nutritious, provided at the same time azote can be supplied from some other aliment containing it, though in small proportion. It seems however that vegetable aliments acquire an accession of azote in the digestive organs, though probably at the expense of some part of the system. Admitting the general correctness of Majendie's views, alimentary substances may be divided into three classes:

I. Those which contain azote, carbon, oxygen, and hydrogen.
II. Those which contain carbon, hydrogen, and oxygen.
III. Those which contain neither azote nor carbon.

The first class naturally demands the greatest share of attention, because "the aliments which contain azote correspond with animal substances in general, and are calculated to repair the waste of our solids and fluids without great alteration or effort in the digesting organs. All the immediate principles of this class are not however equally digestible, or possessed of the same properties." It is necessary therefore to say a few words on the leading forms or states in which azotised principles occur.

Fibrin: this and other terms are retained here, though not in strict accordance with the present chemical phraseology with respect to food and its constituents, because these having been long in use are better known to unscientific readers. The modern views and phrases are all given under the Art. FOOD, in NAT. HIST. DIV. Animal *fibrine*, animal *albumen*, and animal *caseine*, constitute the chief animal proteinaceous principles, that is, compounds of protein and sulphur, and in the two former of phosphorus also. [PROTEIN.]

1. *Fibrin.*—This is found in greatest abundance in the animal kingdom, constituting the principal part of the muscular fibre of animals, and no inconsiderable portion of the blood, when by rest that fluid is coagulated. It has been thought to exist in some of the constituents of the vegetable kingdom, particularly in the juice of the fruit of the Carica Papaya, or papaw-tree, and in certain other plants with a milky juice, such as the Palo de Vaca, Cow-tree (Galactodendron utile) of South America, and some fungi, or mushrooms. The identity of the principle found in these vegetables with animal fibrin has been questioned by some recent chemists. Dr. Thomson considers the principle of the cow-tree distinct, and terms it galactin, while Gmelin terms that of the others emulsin, which he considers analogous to gluten.

Fibrin constitutes the chief part of the solid matter of the muscles of animals, particularly of those which are old and have dark-coloured dry flesh: it is that portion which remains in the form of fibres after all the soluble matters have been removed from the flesh of animals by long boiling. It is insoluble in cold water, is corrugated by long boiling in water, is insoluble in alcohol, but strong acetic acid causes it to swell considerably, rendering it transparent like cartilage, in which state it may be dissolved, or, at least, diffused through water by long boiling.

The flesh of animals is divided into white and coloured, and indeed it differs in the same animal at different ages, having different accompanying constituent principles at different periods of life. Thus in the calf the muscles are white, or only pinkish; in the ox they are deep red; in the first state much gelatin and little of ozmazome is present; hence the gravy of veal easily gelatinises, while that of beef rarely does so.

Fibrin is in general more tender, that is, more easily digested, because the force of aggregation is more easily overcome by the powers of the stomach in middle-aged than in old animals, and in the flesh of the female than that of the male, unless the males have been castrated when young.

Albumen is another important constituent of animal bodies, but of more sparing occurrence in vegetable substances. In animal substances it occurs in two states, fluid and coagulated. The most perfect examples of it in the former state are the white of eggs, which is an alkaline solution of albumen, and the blood, which is likewise probably an alkaline solution of albumen. Coagulated albumen constitutes cartilage, horn, hair, and the nails or hoofs of animals. It forms the chief constituent part of oysters, muscles, snails, &c. Milk is an albuminous fluid.

At the temperature of 165° Fahr. albumen is coagulated, and it is likewise solidified by many acids, such as that of the gastric juice (in the form of rennet), and by some metallic salts. Milk, though coagulated by acids, is not so by boiling.

Albumen is likewise found in the green feculæ of plants in general, and in some vegetables in very considerable quantity, such as the fruit of the *Hibiscus esculentus*, or *Ochro*, and the bark of the *Ulmus campestris*, or elm. The former is used in Sicily to thicken soups, and both are used in the West Indies to clarify sugar.

Animal caseine, the portion of milk which is coagulated by rennet, and some acids out of the body, and by the gastric juice in the stomach, constitutes curd. In the milk it is kept in a fluid state by the alkaline principles present. These are neutralised by the acids.

Gelatin abounds in most animal substances, and is common in proportion to the youth of the individual. It exists in bones, ligaments, tendons, membranes, skin, muscles, as well as in a portion of the horns of animals. The skin of fish, much of their substance, and the swimming-bladder of the sturgeon, are formed of gelatin. It is remarkably bland and nearly insipid, as may be remarked in any solution of isinglass. Gelatin is not of common occurrence in the vegetable kingdom, and it is distinct from vegetable jelly. It occurs, however, in the *Protococcus nivalis*.

Gelatin is the opposite of albumen in its qualities; in cold water it swells, is not transparent, is soft, and somewhat elastic. The gelatin of isinglass and of young animals is slowly but completely soluble in scarcely tepid water, while that of old animals, of skins, and of hoofs or feet, requires warm water for its solution. The solution, when of a certain strength, gelatinises into a tremulous or solid jelly. It is a highly nutritious principle, but its digestibility is, in popular estimation, much overrated.

Mucus is a principle probably found only in animal structures, unless it exists in some plants of the tribe of *Boraginaceæ*. It differs from albumen principally in not being coagulable by heat, while it differs from gelatin in not being precipitated by vegetable astringents, though tannin coagulates the watery combinations of mucus: neither does a concentrated solution of it gelatinise on cooling. Mucus is a constituent of most of the secretions of animals, particularly of the membranes termed mucous. It is deemed both nutritious and of easy digestion.

Osmazome, animal extractive, or alcoholic extract of flesh, is deemed the principle to which meat owes its sapid taste and odour when dressed. Berzelius is disposed to refer these qualities to a watery extract of flesh, which he terms *zomoidin*. Osmazome is by no means a simple, but, on the contrary, a very compound substance, consisting of at least two different extractive materials, lactic acid, several salts, alkalies in combination with hydrochloric acid and lactic acid, &c.

It is probably limited to the animal kingdom, though a substance strongly analogous to it is found in many mushrooms, or fungi, namely, the common mushroom (*Agaricus campestris*), the *A. muscarius*, *A. bulbosus*, *A. thejogalus*, and in the sporidia of the *Elaphomyces officinalis*. This principle is not soluble in alcohol, and to distinguish it from osmazome it is termed Pilzosmazom; to it different fungi owe, when dressed, their savoury odour, resembling that of animal food, and probably a portion of their nutritious property.

Osmazome exists sparingly in young and white meats, which consequently are deficient in savour; it is more abundant in that of animals of which the flesh is red, such as beef and mutton; it exists chiefly in the fibrous organs, or combined with fibrin in the muscles, but the tendons and gelatinous organs are, in a great measure, destitute of it. Animals with dark-coloured flesh, such as the hare, and different kinds of game, possess most, and hence are much esteemed by the lovers of savoury viands.

Gluten is, of all vegetable principles which occur in considerable quantity, the one which contains most azote, having from 14 to 20 per cent. Cafeine, or the alkaloid of coffee, possesses a much larger proportion. Gluten is met with, associated with starch and other matters, in the seeds of the cereal grains, in several other seeds, in many fruits, and in all green and other sappy parts of plants which yield feculæ. When separated from the principles with which it is usually associated, it is, when moist, a white, soft, elastic, and highly glutinous substance (bird-lime); when dry, it is white or whitish gray, hard, of a dull shining and conchoidal fracture. It is without smell or taste, insoluble in and heavier than water. Under ordinary circumstances, about a fourth part of what is termed gluten consists of a principle called *gliadin*. What remains after the removal of this and other matters present with it, is, according to Taddei, pure gluten, which he names zymoian. In the fleshy seeds of pulse, such as beans and peas, exists a substance resembling gluten, called *legumin* and also *vegeto-animal substance*.

Gluten is found in many esculent plants, such as the leaves of cabbages and cresses, and in other edible cruciferous vegetables. Of the nutritious powers of gluten, separate from the starch, fat, gliadin, &c., with which it is always associated, nothing certain is known. In a state of combination, such as that of wheat-flour, it is highly nutritious. Such also is the character of the seeds of peas, beans, and other edible pulse.

Fluids which contain at the same time any of the varieties of sugar and of gluten, or gluten-like principles, are capable, under favourable circumstances, of undergoing the vinous fermentation. A kind of fermentation occurs, by the agency of the gluten, in the conversion of wheat-flour into bread.

Emulsin (vegetable albumen, vegetable casein, or amygdalin) occurs in most of the elaborated juices of plants, and in many dry parts of plants, namely, in all oily seeds which when triturated with water form an emulsion. The real nature of this principle is not clearly ascertained. Many chemists deem it identical with animal albumen; others consider it identical with the casein of the milk of animals; while others pronounce it to be gluten. To Gmelin it appears distinct; he has accordingly given it the above name. Legumin is the term given to some forms of this principle.

II. Proximate principles which consist of oxygen, hydrogen, and carbon, called hydro-carbonates.

Gum is a principle of vegetables, in all of which, but mostly in the soft parts of them, it is found; in some, however, it abounds so much as to form their chief characteristic: they are thence called mucilaginous, or gummy, such as the carrot, parsnip, &c. Gum is colourless, but from admixture of other matters it is often of a yellow or brownish hue, transparent or translucid, of an insipid rather sweetish taste, and not crystallisable. When pure, it is entirely soluble in water, whether warm or cold, forming with it a tenacious fluid; it is insoluble in alcohol. In the state of solution in which it occurs in plants, of which it forms the chief material for their nutriment, it is termed *mucilage*. From some trees, either by spontaneous cracks or incisions, it exudes and concretes on the bark, as is seen in the various acacias, which yield the *gum arabic*, the plum, and cherry trees, &c. There is some difference in chemical character in the various sorts of gum, according to the plant which yields it, but these scarcely affect its nutritive properties. The principle which is found in many fruits, such as the gooseberry, currant, orange, &c., which is *vegetable jelly*, is regarded as a kind of gum, though designated *pectin*. This is neither acid nor possessed of basic properties, and the reason why it so often seems sour is by being united with vegetable acids (malic, citric, &c.), which communicate to the juices of these fruits their taste, and also enable them to redden litmus paper. The grateful and cooling properties of such fruits is therefore chiefly due to the vegetable acids, while their nutritious qualities depend upon the pectin and other principles. Some of these, such as plums, apples, gooseberries, contain 73 to 80 per cent. of water. (See Johnston's 'Chemistry of Common Life.')

Mucilaginous vegetables are rarely fit for use when growing wild; but they are much ameliorated by the processes of horticulture, having their bulk increased and their qualities improved; those which are bitter or narcotic, as endive, lettuce, sea-kale, &c., being by blanching rendered mild and safe, or by being served to table while young, as asparagus. The difference in flavour of such vegetables is due to the principles with which the gum is associated; but their nutritive properties are owing to the gum, which even when taken alone, though mawkish, and at last repudiated by the palate, is certainly adequate to the support of the human frame for many weeks or perhaps months. During the harvest of gum at Senegal the Africans live entirely upon it, eight ounces being the daily allowance for each man. In general they become plump on this fare, and indeed such should be the result, if the calculation be correct which assigns as great nutritive power to four ounces of gum as to one pound of bread.

Sugar is a principle much more abundant in vegetable than animal fluids; it exists however in small quantity as a constituent of the bile, and in the milk of many animals; and it is formed in large quantity as a product of perverted action of the digestive and assimilating organs, in the disease termed diabetes. [DIABETES.] In chemical composition sugar does not differ greatly from gum, except in having a greater proportion of carbon. This additional proportion however is sufficient to confer upon it considerable differences in character. Sugar is of different kinds, according to the plant which yields it, and according to the part of the plant from which it is obtained. Sugars are therefore divided into those which are crystallisable and those which are not, and likewise into those which are susceptible of fermentation and those which are not so. The sugar of the sugar-cane is the most perfect example of those kinds which are both crystallisable and capable of undergoing fermentation; sugar of milk and mannite are examples of the second class. A remarkable feature presents itself in sugars of the first class; for, while susceptible, when dissolved in sufficient water, of the vinous or acetous fermentation, they greatly assist, when concentrated, in preserving vegetable substances, either when naturally present in them, as in many fruits, grapes, raisins, prunes, &c., or when added artificially in making conserves, jellies, &c. Those fruits which grow in seasons favourable to the elaboration of much saccharine matter in their tissues not only keep better, but are more wholesome than when grown in less favourable years. [SUGAR.]

Honey contains a variety of sugar, which is both nourishing and capable by fermentation of yielding mead, which was long the favourite beverage of the ancient Briton. Many fungi, or mushrooms, contain a peculiar kind of sugar, which contributes to render them nutritious.

Starch possesses a larger proportion of carbon than sugar and gum: by removal of this additional proportion of carbon it is reduced to the state of one or other of those principles. This process of reduction occurs spontaneously in the course of flowering in plants, and in the stomach during digestion. When combined with gluten, it is susceptible of fermentation, and by undergoing the *panary* fermentation forms bread, one of the most important articles of food in civilised life. As this is ordinarily managed, some portion of the flour is made to yield up a certain amount of its carbon; but the precise nature of the change which the flour undergoes during this action is not clearly understood. The digestibility of the flour is however greatly increased by this process; and by various admixtures, chiefly of common salt, the taste is improved. [BREAD.]

Starch exists largely in plants, but more abundantly in some parts than others: such as many seeds, particularly of the cereal grains, rice, barley, maize, and millet, in which it occurs in great purity; in wheat along with gluten; with saccharine matter in oats, and some leguminous seeds; with a viscid mucilage in potatoes, rye, and Windsor beans, and occasionally with an acrid principle, which can generally be dissipated by heat, as for example the *Jatropha Manihot*, which yields tapioca. Though seeds and roots yielding starch in abundance are all comprehended under the term *farinaceous*, there are essential differences between them according to the principles with which it is associated, which cause them to differ in their digestibility, and consequently in their eligibility and suitableness for different ages and individuals. Flour, starch, arrow-root, cassada-flour, or tapioca, salep, sago, and other similar preparations, are all merely varieties of the same principle. Starch is not only highly nutritive, but one of the blandest and most wholesome articles of diet, capable, in due proportion, of being used for the food of tender infants, and not improper at any subsequent period of life, though during youth and manhood it requires other principles to be taken along with it.

Oils and *fat*, however much unlike in some respects to the other principles arranged under this head, are formed out of precisely the same constituent elements; and during digestion the stomach brings even the most apparently dissimilar into a degree of relationship more intimate than might have been anticipated. The chief difference between them and the alimentary substances already mentioned, is in their greater proportion of hydrogen. Sugar and starch are both susceptible of fermentation, during which a portion of carbon is removed from each by combining with oxygen and escaping in the form of carbonic acid gas:—from starch in the early stages of fermentation, during which a portion of carbon is taken which brings it to the state of sugar; from which again a proportion of carbon and of oxygen is taken, and alcohol produced, the hydrogen remaining undiminished in quantity:—and as alcohol is merely an oleaginous body of a weak kind, the analogy is complete; for all farinaceous and saccharine aliments undergo changes in the digestive organs before they can be assimilated in the system, similar to what occurs in fermentation, namely, being converted into oil. [DIGESTION.]

Oils are insoluble in water, and therefore, though highly nutritive, they are not available for the support of the body till their immiscibility with water has been overcome. Hence they are apt to oppress the stomach during the early stages of digestion, if taken alone without being mingled with substances which facilitate their union with water. When this is accomplished they are very readily assimilated, as, according to Dr. Prout, "albuminous and oleaginous principles may be considered already fitted for the purposes of the animal economy without undergoing any essential change in their composition."

Oils are either fluid or concrete, and both forms occur in the animal and vegetable kingdoms, though in the latter they are most generally fluid.

Acids are present in many vegetable substances which affect the digestive organs in various ways, though they may not contribute directly to the nourishment of the system.

III. Alimentary principles which do not contain carbon.

Water is the only one of these which it is necessary to notice. This is essential to the existence of all organised beings in whatever way it is introduced into their tissues. Not only is it introduced by human beings in the state of common water, and many beverages of which the chief part is water, but our ordinary articles of animal food contain, on an average, 75 per cent. of water, and only 25 per cent. of nutritive matter; and many of our vegetables contain a still larger proportion.

Such are the chief principles employed by man in a state of civilisation for his subsistence. But it is not enough that a sufficient quantity of one or more of these be swallowed. The function of digestion must be called into action to enable the crude materials to be assimilated. This is partly excited by the mere presence of a substance in the stomach, but more effectually when that substance is in itself of a stimulating quality, or is accompanied by certain accessories either added during the preparation of the food or at meal-times. Such accessories are termed condiments, which either make the food more grateful, or exercise a beneficial influence over the stomach during the process of digestion. The desire to eat is rarely so great when insipid food is offered to an individual as when savoury viands are presented. The very odour or aroma of these excites the salivary glands to more abundant secretion of saliva, which is a preparation for the digestion of the food about to be taken. Though the mere application of heat in the process of cooking developes an aroma from many substances which were previously devoid of it, either by altering the chemical composition of the material, or by volatilising a principle latent in the substance, yet many adventitious articles are used to assist in increasing or modifying this odour, or to correct certain qualities in particular kinds of food which are either disagreeable or injurious. Respecting the most common of these a few words may be allowed. That condiment which is of most universal requirement and utility is salt, or chloride of sodium. It is the only one which is indispensable, for not only does it exist in the milk which forms the earliest nutriment of the infant, but at all subsequent periods of life it is needed. Independently of the part which this compound performs in the stomach during digestion, it is still further serviceable in the blood, and more so in the blood of man than of any other being, as Berzelius has remarked that the blood of man contains three times more hydrochlorates than that of the ox. Besides, the use of salt greatly benefits the alimentary canal and hinders the generation of worms. [ANTHELMINTICS.] It is one of the most ready means of rendering insipid food acceptable to the palate, as is noticed in one of the earliest compositions that have come down to us. "Can that which is unsavoury be eaten without salt?" (Job vi. 6.) Perhaps the next most important condiment is vinegar, which, like most vegetable acids, when taken in moderation, greatly assists in promoting the digestion of young meats of a gelatinous kind, such as veal.

Mustard and pepper of different kinds are also useful, and more so in warm than cold countries, as they rouse the languid stomach, and enable it to effect the digestion of the food. Hot pickles, from containing vinegar at the same time, are often advantageous when used in moderation, but the abuse of such articles produces many serious effects, particularly obstruction of the liver, with its long train of disorders. The use of spices and aromatic agents not only renders the food more pleasant but enables the stomach to bear a larger quantity. Hence they are too often made the means of leading the gourmand to be guilty of excess; and that cook is often most prized who can most cunningly minister to the pampered appetite. This is perverting cookery, a highly proper and commendable art, from its legitimate end. "In the hands of an expert cook, alimentary substances are made almost entirely to change their nature, their form, consistence, odour, savour, chemical composition, &c.; every thing is so modified that it is often impossible for the most exquisite sense of taste to recognise the substance which makes up the bases of certain dishes. The greatest utility of the kitchen consists in making the food agreeable to the senses, and rendering it easy of digestion. But its perfection seldom stops here: frequently among people advanced in civilisation the object to which it aspires is to excite the appetite, to appease capricious palates, or to satisfy luxurious vanity. Then, far from cookery being a useful art, it becomes a real pestilence, carrying with it a train of diseases, and not unfrequently the premature death of many of its infatuated votaries." (Majendie's 'Physiology.') [MILK; WATER; WINE.]

A few remarks are appended to serve as a guide in the use of food and to avoid errors. "Though man is omnivorous, and can subsist on either animal or vegetable food—an arrangement which fits him to dwell in any part of the habitable globe,—yet he is subject with regard to the actual material of his diet, in a remarkable manner, to the influence of climate, since a particular kind of aliment, which is very appropriate in one country is improper in another; thus, as we advance from the equator towards the poles, the necessity for animal food, or its equivalent in a highly nitrogenous class of vegetables, becomes greater, till, in the very north, it is the sole article of subsistence, except a few cruciferous plants, especially *cochlearia* or scurvy-grass, abounding in nitrogen. Animal food, from containing nitrogen, is more stimulating, and, therefore, less suitable for hot climates, where, on the contrary, saccharine, mucilaginous, and starchy materials are preferred; hence, in the zone of the tropics, we find produced in abundance, rice, maize, millet, sago, salep, arrow-root, potatoes, bread-fruit, banana, and other watery and mucilaginous fruits. Quitting this zone, we enter that which produces wheat, and here, where the temperature is lower, we find united with the starch of this grain that peculiar vegetable principle (gluten) possessing all the properties of animal matter, and yielding nitrogen and ammonia by its decomposition. Thus, by a gradual and insensible transition, nature furnishes to man the food which is most appropriate for him in each region. In the subtropical zone vegetable diet is still preferred, but, in chemical composition, the favourite articles approximate animal substances. This holds also in the temperate zone, not only in respect of wheat, but also in the chesnut, which is almost the sole means of subsistence in some of the mountainous regions of France, Italy, and Spain, though instead of the gluten of wheat, this seed contains albumen, the relation of which to animal food is even closer than that of gluten. In reviewing the geographical distribution of the cereal grains, we find that starch nearly pure is produced in the greatest abundance in the hottest parts of the world, particularly in rice and maize; it becomes associated in the subtropical regions with an equivalent for animal food; and in still colder regions, where wheat fails, oats and barley take its place. These, though possessed of less gluten than wheat, are, nevertheless more heating, and therefore, better calculated for northern latitudes. The inhabitants of Scotland and Lapland, with their oaten and barley or rye bread, are thus as thoroughly provided with the best food, as the Hindoo with his rice, or the South American with his Indian corn or maize." (Dr. Robert Dickson: partly founded on an article by Parent Duchâtelet, 'Aliment,' in Dictionnaire de l' Industrie.)

An infringement of the laws deducible from these facts leads to serious (often fatal) consequences. Englishmen going to India or other hot countries, and continuing the habits of their colder native clime, instead of adopting the simpler and more rational diet of the inhabitants, soon induce diseases of a formidable kind. Eating animal food, frequently in excessive quantity, and drinking strong brandied wines, soon cause affections of the liver. (See 'A Treatise on the Diseases of the Liver,' by George Hamilton Bell, M.D., late Resident Surgeon, Tanjore; Edin., 1833, p. 17.) On the other hand, feeding young children in the cold winters of England on rice to any extent, is extremely injurious, leading especially to strumous diseases, particularly of the eye.

Where strengthening the body is the object, and bringing it up to the highest point of health and vigour, a diminution of the fluids in use, and avoiding as far as possible articles of a watery consistence, is requisite. A very large proportion of all substances used as food consists of water. Even lean beef has as much water in its composition as the potato and plantain,—that is, 78 per cent. While using such articles at the principal meal, or dinner, it can scarcely ever be necessary to use fluids or diluents at the same time; yet most persons begin that meal with soups, some very *maigre*, and drench the stomach with water, beer, and other liquids, scarcely any of which are proper, save in a very restricted quantity. When liquids are useful, they may be taken about four hours after the solid meal, whether tea or alkaline drinks, such as soda water or Seltzer water. (See Prout 'On Diseases of the Stomach.') [ALKALIES.] All the most skilful trainers of those preparing for athletic feats rigidly enforce attention to this rule, invariably putting those under their care on what is termed a *dry diet*. Attention to this simple condition will often greatly improve the health of valetudinarians. (See 'Pedestrianism,' by Walter Thom, with an 'Essay on Training,' by the celebrated Captain Barclay, Aberdeen, 1813.) Not only is solid food digested more rapidly than liquid, but the good effects are much more permanent. The practice long indulged in of giving convalescents from acute diseases only weak broths is now mostly abandoned. The articles selected as the basis of these broths were also objectionable, being either veal, chicken, or other insipid material, and the soup often made palatable by adding spices, none of which are proper, save common salt. Young meats abounding in gelatin are less digestible, less nourishing, and in every way less proper than older meats. For persons recovering from what are termed *bilious* attacks, and paroxysms of gout, they are decidedly hurtful. Besides, by long boiling gelatin undergoes a peculiar change [GELATIN, in NAT. HIST. DIV.], which further unfits it for use, perhaps even engendering dangerous products. A well but not overdressed mutton-chop, from which *all the fat has been removed before cooking*, is infinitely better.

White fish, such as whitings, soles, and flounders are often fit for convalescents, being neither too stimulating nor too nutritious, when used without butter or rich sauces. Salt alone is proper. In some hospitals, such as St. George's, London, a fish diet constitutes a part of the diet-table. When jockeys at Newmarket wish rapidly to reduce their weight, they are never allowed meat, when fish can be obtained. (Paris, 'On Diet,' p. 223, 4th edition, 1829.) The oily and red-fibred fish, such as herrings, eels, and salmon, are not so digestible, though more nutritious. When patients in hospitals are permitted to choose their own dinner, they almost invariably select stewed eels, an indigestible food. The apparently highly nutritive power, not to say curative, of cod-liver oil, has led to its very extensive use in the treatment of strumous diseases, especially consumption. Fish, if allowed to ferment or putrify, becomes very stimulating, owing to the disengagement of ammonia. This renders it at first offensive to the sense of smell in those unaccustomed to it. The Zetlanders term such fish "blawn-fish." They are fit articles of food in cold regions, and are used by the Esquimaux. Sir Edward Parry testified to their excellence in this state.

Mushrooms, of which 27 species, native of Great Britain, are esculent, when properly prepared might be more extensively used as food, both by poor and rich, were their distinctive qualities better studied and known. (See Dr. Badham on the 'Esculent Fungi of Great Britain;' and Mrs. Hussey's 'British Mycology.')

FOOD, PRESERVATION OF. [ANTISEPTICS.]

FOOLS, FEAST OF. This was a festival anciently celebrated in different churches and monasteries of Europe and the East, but most perhaps in those of France upon New Year's Day, when every kind of absurdity, and even indecency, was committed. It appears to have been in fact a continuation of the heathen celebration of the January Kalends. Mock popes, cardinals, and bishops, were elected, with ludicrous dancing and singing, intended it is said to ridicule exploded druidism. The council of Basel in 1435 expressed its detestation of this and several other festivals which were then celebrated, and its abolition, at least in one district, was ordered by an arrêt of the parliament of Dijon in 1552. The reader who would know more of this festival may consult Du Cange's 'Glossary, *v.* KALENDÆ,' and Du Tilliot's 'Mémoires pour servir à l'Histoire de la Fête des Foux, qui se faisoit autrefois dans plusieurs Eglises,' 4to., Lausanne et à Genève, 1741.

FOOT. [WEIGHTS AND MEASURES.]

FOOT-BALL, a ball made of a blown bladder cased with leather to be kicked by the foot; used by metonymy for the diversion of driving the ball itself. This was an early and favourite sport with the English. Fitzstephen mentions it among the games of the Londoners in the time of Henry II. Pepys, in his 'Memoirs,' vol. i. p. 324, A.D. 1664-5, says, "January 2, to my Lord Brouncker's by appointment in the Piazza, Covent Garden: the street full of foot balls, it being a great frost." James I. forbade it to be practised near his court as dangerous; but Addison in the 'Spectator,' speaks of a "football match," as one of the village sports patronised by Sir Roger de Coverley. It is still a game much practised by school-boys, and in many rural districts. At Derby it was played till a very recent period by opposing parishes, and not unfrequently attended with serious accidents.

FORCE, a mechanical term, which though it be sufficiently understood in its common and popular meaning, requires some consideration before its strict and philosophical sense can be comprehended.

The term *force* always implies the existence of some cause which produces a visible mechanical effect. Thus the cause of motion and the cause of pressure are both forces: again, difference of effects must be attributed to difference in the producing causes: thus, greater or less velocity, and greater or less pressure, are both attributed to differences in the causes of velocity or pressure. But on the other hand, effects which are the same in one point of view may differ in another; thus, bodies of different weights, let fall from the same heights above the ground, will strike the ground with the same velocities, but with different degrees of effect upon the substance which they strike. Again, if a ball be thrown upwards with a velocity *a*, which carries it to a height *b*, it will, when thrown upwards with twice the velocity, ascend through four times the height *b*. Here, then, considered with respect to one effect, the second force should seem to be twice the first: considered with respect to another, the second seems four times the first. Such difference of appearance in the numerical quantities of different effects led at one time to long and warm disputes on the *proper* method of measuring force, all of which a clearer knowledge of mechanics has shown to be of very little use. One distinct meaning, with care not to assume the consequences of any other meaning as necessarily deducible from the first, will enable the mechanical reasoner to establish the whole doctrine of *statics*, or *equilibrium*: another, the whole doctrine of *dynamics*, or *motion*.

It should seem that these two (so called) *forces* should have different names; but custom has settled otherwise. We proceed to the definitions of force.

In the theory of equilibrium, *force* is a synonym of *pressure*, and *weight* is its measure. The notion of force is here derived, most probably, from the sensation which accompanies muscular effort. Wherever pressure is produced we can find a weight which will supply the place of the pressure: thus, if a string of indian-rubber, hanging from a fixed point, be extended by the hand placed at its lower extremity until its length be doubled, we can, by suspending a weight at the lower end, find what the weight must be in order to produce the same effect. And we then say that the force which the hand exerts is the same as that of the weight. The immediate causes of the effect are very different: our own power of volition, and the connection between the earth and the weight which it draws towards it are (we may safely say, with all our ignorance of causes) extremely different things; but where they produce the same effect, we cease to think of the difference, and say that they both create the same *force* or *pressure*.

In the preceding definition of force, time is not one of the elements. But we very soon observe that wherever pressure is produced motion is prevented. Let the elastic string be suddenly cut in two, and the hand or the weight immediately descends. It is also proved that matter is incapable of producing either rest or motion in itself: if a certain rate of motion be communicated to it, it will preserve that motion unaltered till some external cause interferes. On this axiom the notion of force, as causing motion, depends for precision: the *alteration of velocity* is the evidence of the existence of force.

When force, in the sense of pressure, is considered as the cause of motion, or rather of change of motion, we must take into account both the necessity of introducing the element *time*, and also the quantity of matter which is moved. No change of velocity can be instantaneously produced: if a billiard ball, moving 10 feet per second, be struck so as to accelerate its motion to 20 feet per second, the accession of velocity is made gradually though rapidly. A stone which has fallen for one second in a vacuum is, at the end of the second, moving at the rate of 32 feet per second: let x be any number or fraction less than 32, and there must be a moment, during the course of the second, at which the stone's velocity is x feet per second. Again, when pressure produces motion, the velocity generated in a given time is less, the greater the quantity of matter to be moved. Let different weights, the first double that of the second, be placed on a table (friction not being supposed to exist) and let given equal weights (say each one ounce) be attached to them by strings and hang over the side of the table: then, supposing the two first weights to be 16 and 8 ounces, the pressures are in both cases the same, namely the weight of one ounce; but the masses of matter moved are 17 and 9 ounces (for in both cases the moving ounce is part of the whole quantity moved). The velocities at the end of any given time are found to be *inversely* as 17 and 9: so that by the time a velocity of 9 feet per second is created in the mass of 17 ounces, 17 feet per second is created in that of 9 ounces. The connection of pressure, velocity created by pressure, and time which pressure takes to create velocity, as deduced from experiment, is contained in the following results:—

1. The same pressure continually acting upon a given mass for different times produces velocities which are proportional to the times, and augments velocity by equal portions in equal times.

2. The same pressure applied to different masses of matter (that is, to different weights of matter) during the same time, produces velocities which are inversely proportional to those masses.

3. The velocity of falling bodies is accelerated by 32·19 feet in every second: and in that proportion for all other times.

If then a pressure which is the same as that of a weight V produces motion in a mass of matter whose weight is W, during t seconds, then because the weight of V acting upon the mass of V for that time would produce $32{\cdot}19 \times t$ feet of velocity, we have

Velocity produced by V acting on V (or $32{\cdot}19 \times t$),
is to velocity produced by V acting on W (which is to be found),
inversely as V to W, or as W to V: whence

velocity acquired is $\frac{V}{W} \times 32{\cdot}19\,t$ feet per second.

If it were required to reduce the weight W, having a velocity v, to a state of rest in a given time, say t seconds, and if P were the pressure requisite to be applied to W during the t seconds to produce this effect, we must remember that the velocity destroyed by a pressure in any direction is the same as would have been created in the same time in the opposite direction, if the mass in question had been already at rest. Thus,

$$\frac{P}{W} \times 32{\cdot}19 \times t \text{ must be} = v \text{ or } P = \frac{W v}{32{\cdot}19\,t}$$

Hence, in different masses, the pressures necessary to destroy the motions in the same given time are as the products of the masses and velocities. Thus,

The pressure which will in one-hundredth of a second reduce to rest a mass of 10 ounces moving 100 feet per second, is to the pressure which will (also in one-hundredth of a second) reduce to rest 20 ounces moving 85 feet per second, as 10 × 100 to 20 × 85, or as 1000 to 1700. It is customary to call this product of mass and velocity the *momentum* or *moving force* of the body. [MOMENTUM.]

When bodies are in motion, and with a continually varying velocity, it becomes desirable to consider their motion, not at all with reference to the masses which are moved, and solely with reference to the alterations of velocity which are produced. Thus if a feather and a cannon-ball move together in the same way, the force that is exerted upon the feather is the same in motive effect (upon the feather) as that which acts on the ball (upon the ball). It is customary to ascertain the amount of velocity which would be produced in one second if the acceleration, such as it is at the point in question, continued uniformly. [ACCELERATION.] And this result is called the *accelerating force:* for which the simple term *acceleration* might be advantageously substituted. It is found by the rules of the differential calculus in the following manner (for the demonstration, see VELOCITY). If a point move in a line in such a manner that x feet is its distance from a given point in the line at the end of the time t seconds, and if x be a function of t, then the velocity of the body (v) at the end of the time t is $\frac{dx}{dt}$ feet per second, and the acceleration which that velocity is then undergoing is such as, if allowed to continue uniformly for one second, would increase the velocity by $\frac{dv}{dt}$ or $\frac{d^2x}{dt^2}$ feet. Thus, if $x = t^2 + t^3$, or if a point move through $t^2 + t^3$ feet in t seconds, the velocity at the end of that time is $2t + 3t^2$ feet per second, and its acceleration is $2 + 6t$; or (for instance) at the end of 10 seconds the velocity (320 feet per second) is undergoing acceleration at a rate which would, if continued undisturbed for one second, add 62 feet in that second: or at the end of the *eleventh* second, the velocity would be 382 feet per second.

If f be this accelerating force, we have then

$$v = \frac{dx}{dt}; \quad f = \frac{dv}{dt} = \frac{d^2x}{dt^2}; \quad v\,dv = f\,dx.$$

These are called the *equations of motion.*

Any unit of time might be chosen instead of one second, but not without the following caution. Let g be the velocity generated by a force acting uniformly for one second; then $60\,g$ is the velocity produced in 60 seconds or in one minute. If then we measure the acceleration by g, when the unit is one second, it might seem that we should use $60\,g$ instead of g, when the unit is one minute. But it must be remembered that when we use the minute as a unit of time, we must measure velocities by the spaces which would be described in one minute. Now, in the preceding, $60\,g$ means that the body, at the end of one minute, is moving at the rate of *60 g per second;* that is at the rate of $60 \times 60 \times g$ per minute. Hence $3600\,g$ is the measure of the acceleration, when both velocity and acceleration are referred to the minute instead of the second.

Referring to what precedes, we see that accelerating forces (or accelerations) are proportional inversely to the masses in which they are produced, and directly to the pressures which produced them. Thus the pressure V acting on the weight W, produces $\frac{V}{W} \times 32{\cdot}19$ feet of velocity in every second.

The greatest difficulty in the way of the beginner is his liability to confound an increase of velocity with an increase of length described. He should carefully attend to the article ACCELERATION, by which he will see that a *velocity uniformly increasing* causes unequal spaces to be described in equal successive portions of time; while a *uniformly increasing length described* means a uniform velocity, or a velocity which does not change at all.

FORCES, IMPRESSED AND EFFECTIVE. When various pressures act at different points of a system, the forces which act upon any one point are not those which would, by themselves, produce the motion which that point really has, in consequence of the motion of the system. Thus, suppose a pendulum with two balls, one above and the other (which we suppose to be much the heavier) below the point of suspension. The forces which act on the upper ball would, if it were free of the larger one, cause it to descend; while, in consequence of the connection of the two balls, the smaller actually does vibrate like a pendulum turned upside down, or as if its gravitating tendency were upwards instead of downwards. Here is an instance in which the impressed force acts downwards and the *effective* force upwards; that is, the motion which actually ensues is such as would require a force acting upwards to cause it.

One of the most important principles in dynamics is that known by the name of D'Alembert, and is enunciated thus: the impressed forces are altogether equivalent to the effective forces, or if the directions of the latter were all changed, the former would equilibrate them. Suppose an infinitely small portion of time to elapse, during which the different small masses into which the system may be divided receive certain infinitely small accelerations or retardations. From these the effective forces may be deduced, for they are the forces which would severally produce the actual changes of velocity which take place. If then, forces equal and contrary to the effective forces thus deduced were applied at each point, all the motion created by the impressed forces would be destroyed; that is, the effective forces are such as would (applied in contrary directions) prevent the impressed forces from producing any motion. This proof might be put into more accurate language, but it is in substance the one which is usually given. [VIRTUAL VELOCITIES.]

FORCES, PARALLELOGRAM OF. Any two forces acting at the same point, and represented in magnitude and direction by two straight lines, are equivalent to a third force which is represented in magnitude and direction by the diagonal of the parallelogram constructed with the two lines as its sides. [COMPOSITION.] This theorem is frequently called that of the *parallelogram of forces.*

FORCES, PHYSICAL CORRELATION OF. [PHYSICAL FORCES.]

FORCING, in horticulture, is the art of hastening the growth and maturity of flowers, fruits, and vegetables by artificial means.

Many of our finest exotic fruits are indigenous to warmer countries, and would scarcely ripen even in our warmest seasons; but by this art they are brought to great perfection in cold climates, and by advancing or retarding artificially the growing season of hardy kinds they also can be had in regular succession throughout the greater part of the year.

Although forcing to any extent is but of recent date in England, yet it appears to have been practised in other countries at a very early period of time. Sir Joseph Banks, in the 'Hort. Trans.,' cites some epigrams from Martial, to show that hothouses were not unknown to the Romans, and arrives at the conclusion that in all probability they had both vineries and peach-houses, formed of *talc* instead of glass, which is now commonly used. Pliny tells us that Tiberius, who was fond of cucumbers, had them in his garden throughout the year by means of (*specularia*) stoves, where they were grown in boxes, wheeled out in fine weather, and replaced in the night or in cold weather (Plin. 'Hist. Nat.,' xix. 23); whence it may be inferred that forcing houses were not unknown to the Romans, though they do not appear to have been in general use. This branch of horticulture was almost unknown in Britain until the end of the 17th or beginning of the 18th century, and Lady Mary Wortley Montagu, on her journey to Constantinople in the year 1716, remarks the circumstance of pineapples being served up in the dessert at the electoral table at Hanover, as a thing she had never before seen or heard of. Sir Joseph Banks justly remarks, had pines been then grown in England, her ladyship, who moved in the highest circles, could not have been ignorant of the fact. They were however certainly grown at Hampton Court in the reign of Charles II. It is said that the discovery of peach-forcing in Holland arose from an old Dutch gardener having, in a bad season when his peaches would not ripen, accidentally placed the sashes of a hotbed over them, which had the effect of ripening them. Even after forcing was practised to a considerable extent, its principles were so little understood, that fruit procured in this way was nearly destitute of that natural flavour which it acquires when exposed to the genial influence of the sun's rays and to free ventilation.

The fruits of warmer climates, growing in a wild state, enjoy a greater degree of light than it is possible to give them in this country at any season of the year, and this is one of the most important circumstances to attend to in the art of forcing. Nature is in all respects the best guide in these matters, and care should be taken to imitate her as far as possible; first, by taking care that forced plants are exposed to all the light that can be collected; and, secondly, by preserving a due proportion between the quantity of heat and light to which forced plants are exposed; in other words, by not forcing too hard at a season when the sun's rays are least powerful, thus acting in direct opposition to the laws of nature. Attention to this is the corner-stone of the whole process. When early crops are more desirable than high-flavoured fruit, gardeners are obliged to apply heat without reference to the intensity of light; but if this is not the object, forcing should never be commenced before the spring, in order that the fruit may have the greatest degree of light when ripening. These principles are now generally understood and appreciated, and consequently our peaches, grapes, and other forced fruits are even superior to those grown under the clear skies of the south of Europe.

Mr. Knight, president of the London Horticultural Society, recommended the temperature to be kept much lower during night than is generally done, and remarked, "A gardener in forcing generally treats his plants as he would wish to be treated himself, and consequently, although the aggregate temperature of his house be nearly what it ought to be, its temperature during the night relatively to that of the day, is almost always too high." In one of his vineries he always wished the temperature in the middle of a bright day in summer to rise to 90°, and when the leaves of his plants were quite dry, he did not object to 10 or 15° higher. But he most justly adds, that if this is accompanied by a high temperature at night, "it exhausts the excitability of the tree much more rapidly than it promotes its growth or accelerates the maturity of the fruit, which is in consequence ill supplied with nutriment at the period of its ripening, when most nutriment is probably wanted."

The same experienced author recommended the plants for forcing to be rendered, by previous treatment, as excitable as possible, which may be done by ripening the wood early in autumn, and putting the tree into a state of repose, ready to be roused into action by the application of heat.

It appears to be a general rule that plants from warm countries endure with impunity a very high degree of temperature, while those of more temperate regions are impatient of artificial heat, and hence the difficulty of forcing the plants of northern climates; for example, the same degree of heat in which vines flourish would be much too high for cherries, which throw off their blossoms after expansion without setting their fruit. The reason of this seems to be the following: each plant is adapted to the peculiar circumstances in which it is naturally placed; the natives of warm climates are formed to endure heat, and those of higher latitudes to suffer cold; and when these circumstances are reversed, those of cold countries being placed in excessive heat, and those of warm regions in unusual cold, the former are excited by far too much and too rapidly, so that flowers and fruit are developed before the leaves have had time to organise matter to support them; and the latter, if they endure the cold, are not excited, and remain in a languishing unhealthy state. These reasons will at once show the extreme caution which is necessary in forcing the fruits of northern climates, and will at the same time suggest the treatment that plants of such a description require, and which both reason and experience agree in recommending to those who would be at all successful in the art. Firstly, the increase of temperature must be slow and gradual, and never at its highest point exceed 60° or 65° of Fahr. with artificial heat; air must be freely introduced, particularly in fine bright weather, and the house so constructed as to admit of the greatest possible quantity of light, as for instance by having moveable sashes which can be taken off and put on at pleasure.

The Dutch have long been celebrated as excellent forcing gardeners, and as their manner of performing the operation is peculiar, a description of it may be interesting. The principal feature in their system is conducting the operation chiefly in frames, and pits heated with fermenting dung. The trees employed in forcing are generally taken from a wall in the open air, planted in a rich border of leaf mould, and trained to a trellis a few inches below the glass; here they remain until they have ripened their fruit, after which they are moved back to the wall until wanted for the same purpose in some succeeding year; they never force from the same plant two years in succession. Their system of employing dung instead of fire heat gives them an excellent opportunity of forcing vegetables, such as French beans, endive, lettuce, &c., which are either placed on, or plunged in, the bed in the inside of the frame.

Although pit and frame forcing is a principal feature in the horticulture of Holland, yet they have now, as well as in this country, more elevated structures.

The Dutch plan of forcing has been practised to a considerable extent in gardens in Britain, particularly in that of P. C. Labouchere, Esq., Hylands, near Chelmsford, of which a full account is given in the first vol. of the 'Gardener's Magazine,' and another interesting paper upon the same subject, communicated to the Horticultural Society by M. Lindegaard, is published in their Transactions, Series I., vol. v. The best information regarding the scientific principles of forcing is contained in the numerous papers scattered through the Transactions of the London Horticultural Society, communicated by Mr. Knight and other scientific individuals, and in Lindley's 'Theory and Practice of Horticulture.' The best practical works upon the subject are those from the pens of Speechly, Sandars, M'Intosh, Errington, Glendinning and Robert Thompson, the contents of which are chiefly given in Loudon's 'Encyclopædia of Gardening,' and in the columns of the 'Gardener's Chronicle.'

FORCING-ENGINE. [FIRE-ENGINE.]

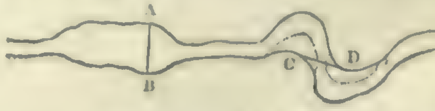
FORD, a name applied to that part of a river where the water is sufficiently shallow to admit of wading through it, and thus crossing over without having recourse to a bridge, a ferry, or other similar means of passage.

Some rivers are never fordable, others are always so; in some the fords are temporary as to season though permanent as to place, and in others they frequently change their situation. Rivers whose banks are steep and course straight are rarely fordable, for in such the water is generally too deep or too rapid to admit of fording. Small and regular streams issuing from springs in flat countries are generally fordable at all times and in all parts. The most common cases, however, are those of temporary and changeable fords. Of the first of these it is observable that when a river has once formed its bed in a soil of a certain degree of tenacity it seldom changes its channel, so that its shallows and deep parts remain constant, and, if the former permit of being forded, nothing but a rise of the waters renders the ford impracticable. This rise depends entirely on the rains which fall into the basin of which the river is the drain and the size of the basin itself, to which two circumstances the river is generally proportionate. If the basin be large and subject to frequent rain the fords will frequently be rendered impassable; if the rains are of long duration, the passage of the ford will be interrupted for a time proportionably long. The channel however remaining permanent the ford may again be passed as soon as the excess of water has flowed off. Such fords have generally been used long before bridges were constructed, and as travellers from a distance sometimes found the ford impassable on arriving, hostelries for their temporary reception were constructed on the banks. Such has been the beginning of many towns whose names still commemorate their origin, as Chelmsford, Bedford, Oxford, Stratford, &c.

Such rivers as flow through a loose soil, as sand or gravel, have generally a very winding course and are constantly shifting their channel, that is, the deep part (which the Germans call the *thalweg*) of their bed. These rivers though they present the greatest number of fords are constantly varying the situation of them, so that they are not only temporary as to season but also as to place. The rains by increasing the mass of water increase the strength and rapidity of the current, by which the bed is ploughed up and deepened in an irregular manner. Banks also are carried away and others formed in parts that before were deep. Thus after every flood the place of the ford is changed.

In the case of torrent rivers, such as those of Italy, fords are very common, but they are subject to be rendered suddenly impassable, or shifted, the waters rising with frightful rapidity to a great height and acquiring amazing force. They however soon subside, and, unless they have deepened the channel, cause no other inconvenience than a very temporary delay.

In military operations fords are of the greatest importance. The inhabitants on the borders of a river generally know where they are, but as their indications cannot always be relied upon, particularly in an enemy's country, the fords must be looked for. They are generally found either in the widest part of the river, or in the direction of the diagonal line that joins the salient angle of one side to the salient angle of the other side, as A B or C D.



In the first case the waters spread out in the wider part of the bed of the river, and are therefore less deep; and in the second, there is always a deposit in front of the salient angles (as indicated by the dotted lines) and consequently the water is more shallow in those parts.

Fords for infantry should not exceed the depth of three feet, and for cavalry that of four feet. These are the extreme depths, and if the current be somewhat rapid it is dangerous to risk fording through more than two feet water for infantry and three for cavalry. The bottom must also be firm and even. Mud, weeds, or blocks of stone are great obstacles—loose sand is also bad as a ford for cavalry, for, being stirred up from the bottom by the horses, it is carried away by the stream, and the ford thus becomes so deep that the last horses in such case are frequently forced to swim. The opposite bank must also be easily accessible and clear, for it is useless to cross a river when, on gaining the opposite side, your further progress is impeded by rocks or impassable forests, thick brushwood, or swampy ground. Having discovered a ford, it is indispensable to mark its situation, and if some time should have elapsed previous to conducting the troops to it, the ford should be again examined in order to be sure that the waters have not risen, or that the enemy may not since have rendered it impassable, which may be effected in different ways. Other considerations are necessary when the ford is to be passed in presence of an enemy, but these belong to a different subject.

FORECLOSURE. [Mortgage.]

FOREMAN. [Jury.]

FORESHORTENING (in Italian *scorciare*, *scorcio*) is a term chiefly applied to anatomical drawing when one or more limbs of a figure, or its entire body, are shown so as to be *shortened* by being viewed directly in front or nearly so, and the spectator seeing little more than its *fore* end, or that which is towards him. Thus, supposing an extended arm and hand to be nearly opposite the eye, and perpendicular to or forming a right angle with the picture, little more than the tips of the fingers or thickness of the arm would be visible. Hence, as perspective has been defined to be the art of foreshortening objects, foreshortening may be explained as linear perspective applied to the human figure, this being the principal case which admits of striking perspective effect in such objects; because when, as for the most part happens, the limbs are beheld in their full or nearly their full extent, let the attitude be what it may, the outline is little affected by mere perspective; consequently, except in ceiling-pieces, where the figures are supposed to be above the spectator, and seen from below the plane on which they stand, foreshortening—at least any considerable degree of it—is rarely required in delineating the human figure; while, on the other hand, it occurs more or less in the figures of almost all animals, their forms being more compounded and their bodies placed horizontally. An example of *foreshortening* may therefore at any time be obtained by standing either in front or behind a horse, when the hind or fore-legs, as the case may be, will be nearly concealed by those towards the eye, and the back of the animal or its length be no longer visible. In sculpture, unless it be in reliefs, the foreshortening of the limbs depends entirely upon the station chosen by the spectator himself; whereas in painting it depends upon that chosen by the painter for him; and several fine examples of it occur in the works of Michel Angelo, Correggio, and Rubens.

FOREST, an extensive tract of ground overgrown with trees alone, of one or several species, or with trees and underwood.

Forests are not only highly interesting in themselves, but are of most extensive importance, whether as regards their influence in the general economy of the globe or on local climate; as supplying to man those necessary articles timber and fuel, besides a variety of nutritious, medicinal, and tinctorial plants; or finally, as affording shelter to wild animals, which finding in them both food and security, leave man unmolested, except when the inclemency of the weather or the scarcity of food impels them to seek the inhabited country.

In taking a view of the forests which cover such immense tracts of the earth's surface, the first thing which strikes us is their variety. In one place they are composed of palms, in another of oaks, and elsewhere of pines and birch trees, &c. We are next surprised at the apparent dissimilarity of situation in which we find collected together trees of the same kind; palms in America, in Africa, and in Asia; oaks and pines in Russia and Mexico, in plains and on mountain tops. A little consideration, however, will satisfactorily account for this. Trees like other vegetables, require, according to their several natures, and independent of suitable soils, different modifications of heat, light, and moisture,[*] circumstances which, so far from being influenced by latitude alone, are much more dependent upon height above the level of the sea, the vicinity of the sea, and other circumstances, than upon proximity to or distance from the equator. Hence, not only do we find particular kinds of trees associated in those regions which are most conducive to their perfect development, but as we find regions of similar climate in different parts of the world, so do we find them producing vegetation of similar character, and thus, though the torrid zone has forests peculiar to itself, we there find also, but at different heights above the sea, the forests of what are termed the temperate and frigid zones. It is, however, remarkable and not easily accounted for, that, although the same trees seem to require similar climates, these climates do not always give birth to the same kind of plants. The greater part of our European forest trees, even the hardiest, disappear towards the Tobol and the Irtish. They do not grow in Siberia though the climate is the same. The oak, the hazel, and the wild-apple are not found from the Tobol to Dauria, although the two first appear again suddenly on the borders of the Argoun and the Amur, and the last is again found in the Aleütian islands.

According to Humboldt, whether we ascend from the plain of Oratava to the top of the Peak of Teneriffe, or from the shores of the Pacific to the summit of the Mexican Andes, we find different zones of vegetation, in which the succession of forest-trees follows, generally, the same order that is observed in passing over the surface of the earth from the equator towards the poles. Ramond, also, in the Pyrenees, and Tournefort on Mount Ararat, found in ascending these mountains, the same succession of trees as exists in passing from their particular latitudes towards the frozen regions. From this fact it has been rather rashly concluded, that certain heights correspond in the nature of their vegetation with certain latitudes: this, however, is not strictly the case, nor is the succession we have mentioned absolutely that observed in proceeding from the equator northward. The extreme heights at which certain forest-trees vegetate in the Andes are different from those at which similar trees are found in the Pyrenees, and while the birch is nearest the snow in Lapland it is succeeded in the Alps by the pine. These variations are explained by a difference in some of the elements of local climate, and by the probable fact of particular primitive distribution. It is also remarkable that in some cases forests are composed solely of some particular tree. Thus, in Lapland there are extensive forests of birch without a single tree of any other kind, and without underwood. In Mazovia also are extensive forests of nothing but birch. In Norway, Sweden, and Finland many forests consist exclusively of pine. Asia has whole woods of nothing but cocoa-nut, &c.

It has resulted from the investigations of M. Alphonse de Candolle, in geographical and geological botany, as modified by those of the late Professor Arthur Henfrey, of King's College, London, that ligneous plants established themselves in northern and temperate countries, at an epoch when the climate must have been more humid and more cloudy than it is at present. The destruction of forests to clear land for cultivation, changes the whole face of vegetation, and even to some extent (as remarkably exemplified in India) affects the local climate. Instances of this kind might be furnished from almost every part of the globe. At the present time, regions in the South of Europe, North Africa, the Canaries, the Southern United States of North America, and elsewhere, once cleared and exposed to the influence of the sun, do not become clothed again by forests such as they possessed formerly. North Europe was clothed in early times of the historical period, forming the later part of the present geological period of the earth's history, with dense forests, long since cleared away to give place to cultivated plants, and a multitude of wild plants suited to the different conditions of the soil; in like manner as the forests of North America are disappearing by degrees under the hand of man. The change is not merely one kept up by a continual effort of cultivation; the original vegetation does not always re-establish itself even when the region is deserted. New kinds of plants spread over the cleared ground, and new animal inhabitants come to check the efforts of the old forests to renew themselves. Coniferous and amentaceous plants, which form the chief constituents of forests in these regions, are phanerogamia of low organisation; and this fact leads to a conclusion of great interest in the history of plants, and perhaps of organic beings generally. The probable antiquity of the groups just named, judging from their occurrence in masses in certain countries, confirms, according to the eminent botanists whose views we are citing, the opinion that existing species are of unequal antiquity, and that the older species are of lower type.

Our European forests, generally considered, are composed of oak, elm, ash, beech, alder, poplar, willow, plane, birch, and lime, together with interspersed wild-apple, pear, and cherry-trees, dogwood, hawthorn, and service-tree; the underwood being hazel, elder, buckthorn, viburnum, dog-rose, &c. Yew and holly are the evergreens of our woods, and of coniferous trees we have the larch, different species of the pine and fir, the cypress, and the juniper.

Forests of Great Britain and Ireland.—The British isles, like other countries of Europe, were in former times much more abundantly covered with timber than they are at present. The increase of population tends to the destruction of forests by causing a demand for the productions of arable land; and this, together with the prodigal expenditure of wood, when it is abundant, and the general and long-continued neglect of any measures tending to ensure a constant supply, have been the chief causes of the great diminution of wood. But though we have now hardly any forests of considerable extent, there are perhaps few countries over which timber is more equally distributed, that is, in those counties where the soil and aspect are favourable to its growth. Woods of small extent, coppices, clumps, and clusters of trees are very generally distributed over the face of the country, which, together with the timber scattered in the hedge-rows, constitute a mass of wood of no inconsiderable importance.

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[*] In this article, as originally published, and agreeably to what was believed at the time, atmospheric pressure was enumerated among these circumstances; but this has since been found to be a theoretical generalisation which facts do not support. Science is indebted for the correction to Dr. Joseph D. Hooker, F.R.S., who has stated that he knows of no foundation for the hypothesis that an alpine vegetation may owe some of its peculiarities to the diminished atmospheric pressure. Many plants, he observes, natives of the level of the sea in other parts of the world, and some even of the hot plains of Bengal, ascend to 12,000 and even 15,000 feet on the Himalaya, unaffected by the diminished pressure. Any number of species from low countries may be cultivated, and some have been, for ages, at 10,000 to 11,000 feet, without change. It is the same, Dr. Hooker also states, with animals (and also with man up to the elevation of about 14,000 feet); innumerable instances may with ease be adduced of pressure alone inducing no appreciable change, whilst there is absence of proof to the contrary. The affections both of plants and animals which have been attributed to this cause, appear to be occasioned in reality by the other phenomena which accompany diminished pressure of the atmosphere.—('Himalayan Journals,' vol. ii., pp. 413-415.)

In Herefordshire, Warwickshire, Northamptonshire, and Staffordshire is abundance of fine oak and elm woods. In Buckinghamshire there is a quantity of birch and oak, and also fine beech. Sussex, once celebrated for the extent and quality of its oak forests, has yet some good timber; at present its woodlands, including coppice-wood, occupy 175,000 acres. Essex, with 50,000 acres of woodland, has some elms and oaks. Surrey, Hertfordshire, and Derbyshire abound in coppice-woods. In Worcestershire is abundance of oak and elm. In Oxfordshire there are the forests of Whichwood and Stokenchurch, chiefly of beech, with some oak, ash, birch, and aspen. Berkshire contains a part of Windsor forest; and Gloucestershire, the forest of Dean; so that these three last counties are extensively wooded, and with noble trees. Cheshire has few woods of any extent, but the hedge-row timber and coppices are in such abundance as to give the whole country, especially when seen from an elevation, the appearance of a vast forest. Of the remaining counties, some have very little wood, and a few are altogether without; but the want and value of timber have given rise to a great many flourishing plantations. Of late years the flanks of the Cumbrian mountains, the sides of the fells, and the borders of the lakes, in Cumberland, Westmoreland, and Lancashire, have been extensively planted, chiefly with Scotch fir and larch. In Wales also, there is a rage for planting. In South Wales alone six millions of trees, it is said, are annually planted; if that is the case, nine-tenths of the number must come to nothing, or the whole country would be one entire forest.

Scotland has few forests of large timber, if we except the woods of Inverness-shire and Aberdeenshire. In the former of these counties the natural pine-woods exceed the quantity of this wood growing naturally in all the rest of Britain. In Strathspey alone there are 15,000 acres of natural firs; and in other parts the woods are reckoned by miles, not by acres; there are also oak woods, and extensive tracts of birch. In Aberdeenshire, in the higher divisions of Mar, there are 100 square miles of wood and plantations. The pines of Braemar are magnificent in size, and are of the finest quality. Argyleshire, Dumbartonshire, and Stirlingshire have many thousands of acres of coppice-wood, and, with a very few exceptions, the remaining counties have many, and some very extensive plantations.

Ireland has every appearance of having been once covered with wood, but at the present day timber is exceedingly scarce in that country, there being no woods, if we except a portion along the sea-coast of Wicklow, the borders of the lake Gilly, in Sligo, some remains of an ancient forest in Galway, and some small woods round Lough Lene, in the county of Kerry. The lakes of Westmeath have also some wooded islands. There are extensive plantations in Waterford, and a few natural woods, of small extent, in Cavan and Down; but Fermanagh is the best wooded part of Ireland. The want of wood however in this country, as far as it is employed for fuel, is little felt, in consequence of its extensive bogs, which furnish an almost inexhaustible quantity of peat.

Upon the whole then, though Great Britain and Ireland do not now possess any extensive forests, still there is a considerable quantity of timber, and the extent of new plantations seems to promise that we shall never be wholly destitute of so essential an article as wood. According to M'Culloch, there is annually cut down in Great Britain and Ireland timber to the value of 2,000,000*l*.

If from our own country we pass over to the continent of Europe, we shall find forests of much greater extent, particularly in the north-east.

Norway.—In the southern part of this country the mountains are covered with wood; birch, maple, pine, and fir, forming immense forests; the fir, sometimes attaining a height of 160 feet, is in great estimation for masts and building timber: in the regions of moderate elevation are aspens. The good lands have some fine forests of oak, which extend as far as Drontheim, in 63° north latitude. The forests of *Sweden* are similar to those of Norway. In the damp places there grows in abundance the almond-leaved willow (*Salix amygdalina*).

Denmark.—Of this country it may be remarked that Jutland, once covered with thick forests, has now only a few long slips on its eastern side. Holstein has very little wood. The island of Funen has some small woods, as also Sealand, in that part of it which borders on the Sound. Falstar is well wooded, and Bornholm has a good deal of birch. In all, Denmark possesses about 130 square leagues of wood, chiefly birch; there is also ash, alder, and oak, but pine and fir are scarce.

Holland possesses timber, though not in very great quantity, generally speaking; what there is, consists of beech, fir, poplar, and ash; willow grows along the canals, and the coppices are of maple, ash, hornbeam, birch, and beech, with a slight portion of oak-bushes. In Guelderland there are plantations of many miles in extent of fir and Weymouth pines, and many hundred acres have been sown with acorns. At Rhenen there are thick woods, as also at Arnheim; and many plantations have been formed on the upper Yssel of fir, pine, oak, beech, and birch.

Germany is so well-wooded that the forests are estimated to cover about one-third of the whole surface, though some consider this estimate too large. In *Hanover* are some fine groves, and a quantity of limes and willows planted in rows. This kingdom also includes about three-fifths of the Harz forest. In *Westphalia* there are very extensive forests, one in particular, in the neighbourhood of Osnabrück, is about 32 miles long and 20 broad. These woods, in which there is abundance of the finest oak timber, are stocked with swine, and furnish the hams so generally esteemed over all Europe. In *Brunswick* the woods and plantations cover a surface of near 300,000 acres. *Saxony* is also abundantly supplied with forests and plantations. *Hesse Cassel* has about a million of acres of wood, and the Rhenish provinces are amply furnished with it. *Prussia* possesses about 18 millions of acres of woodland. Near Kunnersdorff is a wood 20 miles in length. The banks of the Oder are well furnished with fine oaks, as also pines, birches, and willows, of extraordinary dimensions; elms do not thrive. In several places the roads for miles are bordered with poplars, and there is abundance of flourishing plantations. *Bohemia* possesses forests of all the trees common in Germany; they are regularly cut, and furnish upwards of 270 millions of cubical feet of wood, of which, as it greatly exceeds the consumption of the country, a considerable part is exported. *Bavaria* grows a quantity of fine oak and beech timber: the principal forests are those of Spessart, the Rhon Gebirge, Zwieslar, Mitten, Kulwald, Retzler, Lorentz, &c.; they cover together a surface of upwards of seven millions of acres, being about 29-hundredths of the whole superficies of the country. In *Wurtemberg*, the forests occupy about one-third of the whole surface. *Baden* counts about two millions of acres of forests, consisting of oak and pine. In the *Archduchy of Austria*, though there are many forests, they have been so long neglected, that wood is comparatively scarce and dear. The *Hungarian states* have, towards the north and west, as also in Transylvania, some very extensive forests: that of Bakony, the most considerable in the country, is full of the finest oaks. The plains are in general bare of wood, but the Carpathians are covered with the dwarf pine (*Pinus pumilio*). The whole country contains about 12 millions of acres of forest. The *Tyrol* abounds in timber, of which a quantity is exported to Venice.

Switzerland is abundantly wooded, particularly with the cone-bearing trees. Oaks are found occupying a region which rises to the height of 2800 feet above the sea, beyond which, and to the height of 4000 feet, there are beech woods; the firs are found at the height of 5500 feet.

France has many fine forests, though hardly sufficient for the consumption of a country where wood is the chief combustible (and indeed is protected as such in the interest of the forest proprietors, to the detriment of the extraction of mineral fuel), and where the state of the arts and general civilisation create a constant demand for large timber and wood of every kind. The variety of climate and position in that country are however favourable to the growth of all kinds of European and many exotic trees; the oak, the birch, the elm, the ash, and the beech, are abundant; the elder grows in the damp places, and the mountains are clothed with pines and fir. The woods are pretty generally distributed over the country; and of the 86 departments into which the country is divided, there are 24, in each of which there are from 100,000 to 200,000 acres of wood, a dozen more containing from 200,000 to 300,000 acres, 6 having from 300,000 to 400,000 acres, and 3 which reckon each above 400,000 acres. The department of Dordogne alone contains upwards of 1,000,000 acres of wood. In all France there is reckoned about 21,000,000 of acres of woods and forests; of which about one-seventh, consisting of 1473 different forests, belong to the state.

Italy, the geographical position and local peculiarities of which are favourable in a high degree to vegetation of every kind, is not particularly rich in forest trees. There is at Ravenna an extensive forest of the stone pine (*Pinus pinea*). The Apennines also have their portion of coniferous trees, and are in some places covered to the top with luxuriant forests of chestnut-trees. The fertile basin of the Po abounds in plantations of olive, mulberry, fig, and almond-trees, while the pyramidal poplar forms a contrast by its tapering form with the flattened and branchy head of the stone pine; and the same may be said of other parts of Italy. In *Sicily* the forests have long since been exhausted, and wood is extremely rare in that island. But in *Sardinia* one-fifth of the surface is covered with ancient forests of oak, among which is the cork oak (*Quercus suber*), the common oak (*Q. robur*), and the evergreen oak (*Q. ilex*).

Spain and Portugal are deficient in wood, both as regards quantity and quality. The peninsula however is not unfavourable to the growth of timber; in the time of the Moors, the southern provinces in particular possessed some noble forests, but they have long since been devastated; and although since the time of Philip II. there has existed an excellent code of forest laws, they are altogether disregarded or evaded. Nevertheless there are still some forests in Spain; thus between the two Bagnères, in the Spanish valley of Aran, and on both sides of the western Pyrenees, there are forests of the silver fir; and on the south side of these mountains, east of Benasque, as also near Mont Pedru, and on the hills surrounding Andorra, are woods of the *Pinus uncinata;* and in the neighbourhood of Campo, in Upper Aragon, are forests of the *Pinus pyrenaica,* or, according to some, the *P. Larichio*, or Corsican pine. On the Sierra de Cuença, the Sierra de Segura, the Nevada, and the Serrania de Ronda, are some tracts of different kinds of pine, as the *P. Hispanica*, or Spanish pine (*P. halepensis*). The Aleppo pine grows in considerable quantities in Catalonia, and in the western part of Andalusia is a forest of the stone pine. The principal forest of Spain however is that of St. Ildefonso, which is chiefly of the Scotch pine (*P. sylvestris*). In the maritime part of the

Basque provinces there is nothing but the miserable *pin des landes.* In Biscay beech only is cultivated; but in Galicia and in Catalonia there are both oak and beech. In Estremadura there are forests of the evergreen oak, which produce the sweet or edible acorn; Catalonia, Valencia, and the environs of Seville, produce the cork-tree (*Q. suber*). This tree, which was formerly abundant in Andalusia, is proceeding rapidly to extinction. Many parts however of the Castiles, Aragon, Andalusia, and Estremadura, are without wood; and although the common oak is found in small quantity in the northern provinces, upon the whole there is a great deficiency of useful wood: all the middle and southern regions hardly produce one good kind of timber.

European Turkey—Of this country it is observable that, on the northern side of the Balkan, in the basin of the Danube, there are fine forests of oak, elm, and pine, and in Wallachia there are whole forests of fruit trees, particularly plum, apple, pear, cherry, and apricot. On the southern side of the chain the forests are particularly varied. Different kinds of pine and fir, oak, maple, sycamore, walnut, chestnut, and beech, are found in succession on the several terraces, while on the mountains themselves forests of oak, elm, and lime, abound. The Morea produces the cork tree, the Kermes oak, the Valona oak, of which the acorns are eaten, the plane, the wild olive, the sweet chestnut, the manna ash, pine, firs, and the larch, the barren date tree, the silk tree, &c., and a variety of plants used in the arts, and in pharmacy.

Russia.—Of all the countries of Europe, Russia is the most abundantly provided with timber; and her forests would be an almost inexhaustible source of wealth, if it were possible for the government effectually to protect them from destruction. In 1802 regulations for the preservation of the forests were established, but such is their extent and that of the country, that it is next to impossible wholly to prevent the waste of wood.

Hermann's 'Statistical Notice of the Agriculture of Russia,' published in the 8th vol. of the 'Memoirs of the Academy of Sciences of St. Petersburg,' and quoted in Mr. Schnitzler's work, states, "there are still 200,000,000 of acres exclusively covered with pine and other cone-bearing trees, without counting oaks, maples, beech, poplar, and hornbeam (none of which are scarce below the latitude of 52°), and birch, which grows further north." In the year 1804 it was estimated that there existed 8,192,295 pine trees fit for masts, being 30 inches in diameter; and 374,804 oak trees, of 24 inches and upwards in diameter; about 87,000,000 more pines were proper for building timber. Enormous as this may appear, the statement, so far from being exaggerated, would seem to be considerably below the truth, it being certain that in the three northern governments alone of Wologda, Archangel, and Olonetz, there are 216,000,000 of acres of forest trees, chiefly pine and fir. Birch, pines, fir, and limes, are the common forest trees of European Russia. The first is the most abundant as far as the 55th parallel, beyond which there are still found vast forests of pine and fir. The governments of Novgorod and Twer are covered with wood; the Volkonsky forest is the largest in Europe. In the government of Perm, of a surface of 50,000,000 of acres, 47,000,000 are covered with forests. Many of these immense tracts of wood are impenetrable, and harbour great quantities of bears, wolves, and other savage beasts, while others abound in deer and game of all kinds. In Esthonia, Livonia, and Courland, there are fine forests of pine, fir, and birch, the latter predominating in the moist places; alder, ash, elm, and plane, are found in the good soils, but oak is in general scarce. In Courland lime is abundant, but beech is rare; there are willows of several varieties. In general it may be observed that, in Russia, the pine, fir, and other coniferous trees, are found as far north as 57°; birch, aspen, and extensive forests of lime, as far as 54° or 55°; oak, rare in the central plateau, prospers towards 51° or 52°, but in the valley of the Volga they are fine and abundant at 55°. In the same region where the oak succeeds the Russian maple (*Acer tartaricum*) is in abundance, as also white poplar and hornbeam. In the central provinces beech hardly reaches Smolensk, and does not pass beyond Little Russia. In some parts of the Ukraine are fine oak forests. In Lithuania the timber is generally fir, intermixed with pine and birch, and occasionally oak. The woods of the latter province harbour bears, elks, &c., and in the celebrated forest of Bielovieje is found the aurochs, a species of wild ox, now peculiar to this locality.

Poland, generally speaking, is covered with magnificent forests; in Mazovia particularly there are some very fine woods. The different varieties of the pine are found in the sandy places, and on the mountains are fir and beech. Oak succeeds well in good soil. In addition to these trees Poland also possesses larch, lime, elm, and ash. In the Buckowine are forests of beech, intermixed with fir and birch woods.

It appears then, that although the progress of civilisation and increase of population have greatly diminished the forests which at one time covered great part of Europe, there is still an immense quantity of wood, and the necessity of keeping up a constant supply being now very generally acknowledged, there is reason to hope that the forests will no longer be abandoned to wanton destruction, but that, on the contrary, the felling of timber and cutting of copse woods will be properly regulated, and fresh plantations made to replace the wood consumed.

We will now take a hasty glance over other parts of the world.

Asia.—In the Caucasus we find that on the western, eastern, and southern slopes of this chain, there are forests of cedar, cypress, juniper, beech, and oak, and on the edges of these, quinces, wild apple, and pear trees; while the warm and sheltered valleys produce the almond, the peach, and the fig. On the borders of the Caspian there are woods of olive, plane, and laurel.

In *Asia Minor*, Mount Taurus is covered with forests of cypress, juniper, and savines. The gall-nut oak grows from the Bosphorus to Syria, and the Persian frontier; oaks and fir abound in the forests along the Black Sea. There are also in different parts woods composed exclusively of fruit-trees. Syria, to a vegetation greatly similar, adds the sycamore and palm trees.

Arabia has no forests, properly speaking. The oases, however, contain groves of date palms, tamarinds, and different fruit trees. In Hejaz the date palm is abundant.

Persia.—In Mekran there are forests of the Indian palm, intermixed with the odoriferous shrubs of Arabia Felix. In the valley of Shiraz we find only clumps of plane trees, weeping willows, and poplars; but the mountains which border the Caspian are covered with oak, lime, acacia, and chestnut: and higher up cedar, cypress, and other pines, with the sumach and the mountain-ash. Ghilan abounds in boxwood, and on the south-east of the Caspian there is great abundance of oak, but no pine.

Siberia is too cold for the oak, the hazel, the alder, the plane, and the wild apple; even the ash ceases towards the Irtish; and the fir, which in Norway grows as far as 70°, stops in Siberia at 60°, while the silver fir goes no further than 58°. The great steppes of this country are nevertheless bounded by thick forests of birch, willow, elm, Tartarian maple, black and white poplar, aspen, and a great variety of firs, among others the Siberian cedar, which sometimes attains a height of 120 feet, and is particularly fine on the banks of the Yenesei. The country between this river and the Baikal is well wooded. At Tobolsk are fine woods of birch, and of the pitch pine. Berezoff has also forests of birch and fir, with stunted Siberian cedar. In the government of Tomsk there are forests of elm, larch, willow, and birch; and between the Obi and the Tom, the land is covered with birch. To the west of Irkutsk the country is nothing but one vast, dense, and swampy forest. At Nertchinsk, in Russian Daturia, forests abound formed of larch, black and white fir, Siberian cedar, and black birch, which latter is found only here. There are also whole forests of wild apricot and rhododendrons. At Ockhotsk there are immense tracts of swampy forests, and Kamtchatka, the eastern limit of the Old World, abounds in larch, white poplar, and birch. The willow and the alder are employed only for fuel. On the whole, Siberia, notwithstanding its immense steppes and marshy plains, still reckons upwards of 2,000,000 of acres of forest in the two neighbourhoods alone of Ekaterinbourg and Tobolsk.

Central Asia is too little known for us to speak with any certainty regarding the forests it may contain. The greater part of the vast plateau of Tartary is a sandy and desert region, except at the immediate borders of the water courses; what forests do exist are on the slopes of the mountains by which the plains and valleys are surrounded. In the province of Leao Tong, in Manchuria, there are some extensive forests of fir, cypress, acacia, willow, apricot, peach, and mulberry, and on the east coast the mountains are covered with oak and pine, while towards the lower lands the willow, the maple, and the azalea are abundant.

Corea has immense forests in the mountains of its northern parts. The islands of *Sagalhin, Jesso,* and *the Kuriles* have large forests of the finest timber.

The *Empire of Japan* has a vigorous vegetation, partaking of the European and South Asiatic; larch, cypress, and weeping-willow, which, by the way, is found in all the temperate countries between the Mediterranean and this empire, are here blended with the cocoa-nut, the fan-palm, and arborescent mimosas.

China.—On the mountains of the western district of this great and populous empire there are forests of immense extent, abounding in almost every species of tree known in Europe, and many others unknown. These forests, besides timber and fuel, supply many valuable productions, such as barks, gums, oils, and resins used in the arts; rosewood, ebony, sandal-wood, and the valuable Chinese aloe; a camphor-tree, which furnishes the best and most beautiful timber, the paper and other mulberries, the tallow-tree, the bamboo, &c. The provinces of Kiang-si and Quang-si have also their mountains covered with forests, and in the latter province there is cinnamon superior to that of Ceylon.

The islands of *Formosa* and *Hainan* are abundantly wooded, producing, besides timber, several woods remarkable for their perfume, and others of great value for carving, as eagle-wood, violet-wood, and a yellow wood of remarkable beauty, said to be incorruptible. Returning to the continent of Asia, we find

Tibet, having the bases of its mountains girded with forests of bamboo, aspen, birch, cypress and yew, and ash of remarkable beauty; pine and fir are low and stunted.

Cashmere has abundance of oak.

India, both within and beyond the Ganges, is rich in wood. There are whole forests of the bamboo, which sometimes attain a height of 60 feet. Cocoa-nut and palms of all kinds cover large tracts. Here are woods of oak, fir, cypress, and poplar; there are mangoes, banian-trees, uvarias, robinias, sandal-wood, &c. Guzerat, Oudepoor, the kingdom of Asam, Bengal (along the coast particularly), the mountains of Tipra, and Malabar, abound in wood: the latter produces teak. In the Birman empire there are magnificent forests of the last-named valuable tree, together with white sandal-wood, eagle-wood, iron-wood, ebony, sycamore, Indian fig, fan-palms, bignonias, coccas, and sago-palms; as also fine groves of orange, lime, &c.

The mass of the forests of the Sikkim Himalayas, according to Dr. J. D. Hooker, commences at about the height of 5000 feet, where the agriculture of the country terminates in ascent; and is formed of—(1) three species of oak, of which *Q. annulata !*, with immense lamellated acorns, and leaves 16 inches long, is the tallest and the most abundant; (2) Chesnut; (3) *Laurineæ* of several species, all beautiful forest trees, straight boled and umbrageous above; (4) Magnolias. Many species of *Magnoliaceæ* (including the genera *Magnolia*, *Michelia*, and *Talauma*) are found in Sikkim. *Magnolia Campbellii*, which grows at 10,000 feet elevation, is the most superb species known. "In books on botanical geography," Dr. Hooker remarks, "the magnolias are considered as most abounding in North America, east of the Rocky Mountains; but this is a great mistake, the Indian mountains and islands being the centre of this natural order." (5) Arborescent rhododendrons, which commence here with the *R. arboreum*. At 8000 and 9000 feet of altitude a considerable change is found in the vegetation, the gigantic purple *Magnolia Campbellii* replacing the white; chesnut disappears, and several laurels: other kinds of maple are seen, with *Rhododendron argenteum* and *Stauntonia*, a handsome climber, which has beautiful pendant clusters of lilac blossoms. At 10,000 feet, as exemplified on the top of the mountain called Tonglo, a great number of additional species of plants are found, and all betoken a rapid approach to the alpine region of the Himalaya. In order of prevalence the trees are,—the scarlet *Rhododendron arboreum* and *R. barbatum*, as large bushy trees, 30 to 40 feet high, both loaded with beautiful flowers and luxuriant foliage; *R. Falconeri*, in point of foliage the most superb of all the Himalayan species, with trunks 30 feet high, and branches bearing at their ends only leaves 18 inches long. Next to these are shrubs of *Skimmia Laureola*, *Symplocos*, and *Hydrangea*, and still a few purple magnolias, very large *Pyri*, like mountain ash, and the common English yew, 18 feet in circumference. A currant is common, always growing epiphytically on the trunks of large trees. Two or three species of Berberry, a cherry, *Andromeda*, *Daphne*, and maple, nearly complete, in Dr. Hooker's opinion, the list of woody plants. The rarity of Pines is perhaps the most curious feature in the botany of Tonglo, and on the outer ranges of Sikkim; for, between the level of 2500 feet, the upper limit of *P. longifolia*, and 10,000 feet, that of the yew, there is no coniferous tree whatever in Southern Sikkim. ('Himalayan Journals,' vol. i., pp. 162–169.)

In some parts of India the entire destruction of the forests has rendered the country liable to the dreadful calamities which follow a deficiency of rain. The north-west provinces were denuded of their trees during the wars that attended the decline and fall of the Mohammedan empire and the rise and progress of the Jâts, Sikhs, and Mahrattas. These lawless freebooters swept away all the groves from the face of every district they invaded, whilst they never thought of renewing them, or encouraging their renewal, in those countries which they permanently occupied. Many fertile regions were thus turned into dreary and arid wastes. For many years past, however, the attention of the Indian government has been given to the protection and renewal of the forests, which are now committed to a special class of officers.

Ceylon is also well wooded with Asiatic trees and shrubs: among the former are the ebony and satin-wood, and of the latter the cinnamon is the most remarkable.

The kingdom of Laos, Tonquin, Cambodia, Siam, and the peninsula of Malacca, have a nearly similar vegetation. Of the kingdom of Cochin-China, including Tonquin, Cambodia, and Cochin-China Proper, it may be said that all parts produce good timber, including, according to Loureiro, teak. The other vegetable products of the forests of Cambodia in particular, which are applied to use, are Cardamoms, Agila or eagle-wood, gamboge, and stick-lac. The Siamese forests also produce teak (north of lat. 16°) and eagle-wood, together with sappan-wood (*Cæsalpinia sappan*), a kind of red wood, called by the resident Portuguese "Pao-rosa," or rose-wood; and a kind of benzoin, differing from that of Sumatra, more abundant, but inferior in quality; and two species of cardamomum, seemingly different from the *Amomum cardamomum* of Malabar. In various parts of the kingdom, especially of its southern districts, the tree or trees yielding gutta percha have been discovered, and the produce exported. The peninsula of Malacca, though luxuriant in vegetation, is on the whole inferior in products to the countries just noticed. There are many species of forest-trees, but not one is fit for the higher purposes of ship-building; teak does not exist; and about six only yield good durable timber. Sappan and eagle-wood again occur, together with ebony, but none of them in much abundance or of the best quality. The most valuable and remarkable product is gutta-percha. [GUTTA-PERCHA.]

Borneo is covered with a rank verdure, or a primeval forest of gigantic trees; the cleared and reclaimed spots forming but exceptional specks in this wild and unvaried landscape. The commercial products are benzoin, eagle-wood, camphor, the sago-palm, and ratans.

The *Philippine Archipelago*, embracing about 16° of latitude and 9° of longitude, and those between the 5th and the 21st degree of latitude north of the equator, is necessarily rich in products of all the kingdoms of nature. No fewer than 218 forest trees, chiefly of the more northern provinces, have been subjected to experiments in the arsenal of Manilla, and the relative strength, tenacity, and specific gravity of the timber ascertained for economic uses. In the most southerly island, Mindano, among many unknown forest-trees, we find the well known teak (*Tectona grandis*), this being, except Java, the only island of the Malay and Philippine archipelagos that is known to produce it in any considerable abundance; while Sumbawa is the only other island of the former in which it is known to occur at all. The intermediate islands of Bali and Lombok do not produce it.

Of *Oceania* it is sufficient to say, that all the islands are more or less abundantly covered with timber; many produce trees of immense size and of the finest wood.

"The whole island of *New Guinea*," or Papua, says Mr. Crawfurd, "so far as it has been seen, is one uniform and luxuriant forest, many of the trees of which run up to the height of 150 and 180 feet. The economical use of the timber of these huge trees has not been determined; but the forests of New Guinea produce three plants which have been immemorially in demand by the nations of the Malayan islands; namely, the true nutmeg (*Myristica moschata*), the missoy, or masui (*Cortex oninus*), and the pulasari (*Alyxia stellata*). If the timber should prove to be of good quality it is probable that it may come to be in demand with the European colonies of Australia, when these attain a dense population."

Australia, from its great extent, varies greatly in its flora. The forests in parts are extensive, and the pine, the iron wood, and mahogany, make good timber; but of many, such as the various species of Eucalypti, the wood is brittle. Many of the native trees are, however, useful for building or other constructive purposes.

New Zealand abounds in forests. The trees and ferns, indeed, give the distinguishing feature to the vegetation. In England, out of about 1400 species of plants, there are not more than 35 native trees. In New Zealand, of flowering trees, including shrubs above 20 feet high, there are upwards of 113, or nearly one-sixth of the flora, besides 156 shrubs and plants with woody stems. Dr. J. D. Hooker thinks that the *coniferæ* will prove, eventually, to be the most prevalent natural family of plants in the islands. The Kauri pine (*Dammara australis*) is not found south of Kawia, on the western coast, and the Bay of Plenty on the eastern. It is confined to the vicinity of the sea, but prefers sheltered localities. The Kauri forest forms a very deep deposit of turfy soil, which, being intermingled with much resinous matter, burns with great facility when dry. The resin of this pine is an important article of commerce with England, and the United States of America. The tree attains the height of 200 feet, and yields an invaluable light compact wood, free from knots, from which the finest masts for ships are now prepared.

Africa.—In spite of the burning heat of a vertical sun, there are in Africa spots which, by reason of their elevation or their proximity to the sea, enjoy a more temperate climate and abundance of moisture. In these places vegetation is rich beyond description. Thus Senegambia, Guinea, and Congo are covered with forests, which consist of the baobab (of which there are different kinds), of palms, robinias, sycamores, sandal-wood (red and gray), and tamarinds, intermixed with bananas, oranges, limes, and pomegranates; there are also cocoa-nut trees in great abundance. The tamarind and cedar, which grow in the greatest profusion on the borders of the Congo, furnish timber of the finest quality. *Abyssinia* has abundant woods, in which grow the smooth-leaved coral-tree (*Erythrina corallodendron*), the tamarind, the date, some mimoseas, and a large timber-tree which Bruce calls *rak*. On the coast of Adel there are odoriferous forests, producing the balm of Judæa, myrrh, &c. *Egypt*, though abounding in plantations of fruit-trees and dates, has no forests. The Atlas Mountains, on the contrary, are covered with magnificent forests, and producing a variety of oaks, the mastic tree, the cypress, &c. In the interior of the Atlas, the environs of Borgou are said to be covered with trees, among which are several kinds of sycamore, palms, and the *Mimosa nilotica*. The kingdom of Bornou has immense forests, and the date-palm abounds here. *The Cape*, celebrated for the beauty of its vegetation, was generally thought to be deficient in forest-timber, but it has been discovered that to the eastward there are forests of the finest oak of the Albanian kind, celebrated for its quality and durability. These forests also produce iron-wood, the sago-palm, &c.; as yet, however, they have been but imperfectly examined. Of the African islands, *Madagascar* is rich in timber, and a variety of woods useful in the arts. The same may be said of the islands on the west coast; they are generally well wooded.

In a general survey of the globe, we may look upon the New World as pre-eminently the land of forests (as will appear when we come to treat of the forest of the Amazon), contrasting strongly with the Old World, where steppes and deserts are the most characteristic features. This fact is probably related to a great element in the chronology of physical geography,—the comparative youth of America (thus new as a part of nature as well as to knowledge) in the present geological period of the earth. The oldest sedimentary formations, the Silurian, Cambrian (and perhaps the more recently recognised Laurentian), strata, appear to be universal; but the periods when they constituted the surface of the land, with their clothing of vegetation and population of animals, belong to the most remote physical antiquity. As land of the present period, with its appropriate organic beings of both kingdoms, of the present period also, including man himself, the great continent of Europe, Asia, and Africa, would appear to be the oldest; America, as a country of the present period, seems to have been produced and peopled next; while Australia, together with the eastern portion of the Indian Archipelago (which, as very recently shown by an accomplished traveller and naturalist, Mr. Alfred R. Wallace, belongs to the same natural region), forms a still newer world. The differences with respect to the association of plants which produces what we term forests, and to vegetation in general, between Australia proper and America, are no doubt dependent principally on the peculiarities of climate of the former, which have already been noticed in the article DESERTS.

America, accordingly, is, of all parts of the world, the most thickly covered with wood. Beginning with the north, we find the Russian territory on the north-west coast abundantly stocked with fine timber: pines 300 feet high and 45 feet in circumference, Canadian poplar, alders 40 feet high below the branches, birch, yew, black and common oak, American ash, sycamore, sugar maple, cypresses 24 feet in circumference, and willows. The islands on this coast have also magnificent forests of pine and other lofty trees.

In *New Britain* the forests are extensive, but they present little variety, and in some parts, to the northward particularly, the larches and birches are stunted in their growth. The environs of Lake Winnipeg are covered with the trees common to Canada.

In *Greenland* there are only a few stunted willows and birches; and *Labrador* has merely some pines and pinasters in the valleys.

Canada contains immense forests. Pines and evergreens are the most abundant, after which come the red and the sugar maple, the birch, the lime, the American elm and iron-wood, the yew, the common and mountain-ash; also a great variety of oaks, different from the European species, which do not thrive here.

New Brunswick has large forests of fine timber, particularly pine, which it exports.

Nova Scotia produces good oak; but the principal wood is pine, fir, and birch.

The island of *Cape Breton* furnishes immense oaks and magnificent masts. *Newfoundland*, and the other islands at the mouth of the St. Lawrence, also produce timber fit for naval and other constructions.

The *United States* are abundantly wooded, the cleared land even in some of the Atlantic states being inconsiderable when compared with that still covered with the primitive forests, which contain an immense variety of trees. There are about forty different kinds of oak, fourteen of pine, besides cedar, cypress, and larch; several maples, among which is that from which sugar is obtained, birch, ash, beech, iron-wood, hornbeam, hickory, wild cherry, and apple, mulberry, poplar, willow, magnolias, elm, chesnut, &c. Of all the states, Ohio perhaps contains the finest forest-trees. The woods of Florida present a mixed vegetation, exhibiting the productions of both the north and the south. Thus there is red and white pine, evergreen oaks, chesnut, mahogany, walnut, cherry, maple, logwood, Brazil-wood, and sassafras. There are also in Florida whole forests of red and white mulberry, the finest in America. All European fruits also grow here, and the oranges are finer than in Portugal. In California the pine attains an enormous growth, and the timber has been found to be of excellent quality. The Oregon territory and British Columbia are both well wooded.

In *Mexico* or *New Spain* there are abundant forests, differing in character according to their position on the heights or in the plains. In Texas there are great plains covered with palms, while the heights are clothed with the timber-trees of Louisiana. The mountains in the neighbourhood of Guanaxuata and Valladolid are covered with forests, and the Intendance of Mexico abounds in cedar and other large trees.

Yucatan is famous for its logwood and mahogany; the latter is also produced in great abundance round the *Bay of Honduras*.

Nicaragua has groves of palms which attain an immense magnitude; and in *Costa Rica* and *Varaguay* there is fine forest-timber.

The *West India Islands* generally abound in wood, though there are exceptions.

In *South America* the Caraccas possess inexhaustible forests, which, besides the finest timber, produce also a great variety of beautiful woods for cabinet-work, dye-woods, drugs used in the arts, and medicinal plants, as the sarsaparilla, bark, &c.

In *New Grenada* the plateau of Bogota, Popayan, and Pasto have fine forests. The neighbourhood of Guayaquil, besides the common timber of the country, possesses a wood remarkable for strength and solidity, which is said to be incorruptible, and to resist worms better than any other; qualities which render it invaluable for the keels and ribs of vessels.

Peru is rich in forests, which furnish timber, gums, resins, dye- and cabinet-woods, all of the finest quality.

Chile possesses forests of gigantic trees, many of incorruptible wood, and others useful for their gums, resins, &c. Pines and cedars are abundant. The whole chain of the Andes abounds in wood, varying in kind according to height, latitude, and aspect. The vigour of the vegetation in some parts is inconceivable: thus in Chile trees have been found so large, that an entire church, 60 feet long, with all its wooden appurtenances of doors, windows, &c., has been built of a single tree.

The *Magellanic Lands*, on the west or mountainous part, contain forests.

Paraguay is rich in wood, on the borders of the Upper Uraguay; and, among other trees, produces in abundance that from which the resin termed dragon's-blood is obtained.

Brazil contains extensive forests, which cover immense tracts, and are composed of palms, Brazilian cocoa, loftier than the Indian, together with an endless variety of other trees peculiar to the country: some of these are of extraordinary size. The Brazilian pine furnishes very fine masts: this country exports a large quantity of timber, and supplies all the Portuguese shipping. Brazil also produces the dye-wood which bears its name.

Guiana has extensive forests in its higher parts; but the wood of many of the trees is so soft as to be only good to burn, and that of others is too hard to be worked. It produces many dye-woods.

The forest-region of the river Amazon and of the upper Orinoco, according to Humboldt, covers an area of about 719,000 square miles.

The entire extent of the valley of the Amazon, with the exception of some very small portions, is covered with one dense and lofty primeval forest, the most extensive and unbroken which exists upon the earth. It is the great feature of the country,—that which at once stamps it as a unique and peculiar region. Here we may travel for weeks and months inland, in any direction, and find scarcely an acre of ground unoccupied by trees. It is far up in the interior where the great mass of this mighty forest is found; not on the lower part of the river, near the coast, as is generally supposed. A line from the mouth of the river Parraiba, in long. 41° 30′ W., drawn due west towards Guayaquil, will cut the boundary of the great forest in long. 78° 30′, and, for the whole distance of about 2600 miles, will have passed through the centre of it, dividing it into two nearly equal portions. For the first 1000 miles, or as far as long. 56° W., the width of the forest from north to south is about 400 miles; it then stretches out both to the north and south, so that in long. 67° W. it extends from 7° N., on the banks of the Orinoco, to 18° S, on the northern slope of the Andes of Bolivia, a distance of more than 1700 miles. From a point about 60 miles south-east of Tabatinga, a circle may be drawn of 1100 miles in diameter; the whole area of which will be virgin forest.

"The forests of no other part of the world," observes Mr. A. R. Wallace, from the scientific additions to whose 'Travels on the Amazon and Rio Negro' we derive these corrected particulars of the forest-region of the Amazon, "are so extensive and unbroken as this. Those of Central Europe are trifling in comparison; nor in India are they very continuous or extensive; while the rest of Asia seems to be a country of thinly-wooded plains, and steppes, and deserts. Africa contains some large forests, situated on the east and west coasts, and in the interior south of the equator; but the whole of them would bear but a small proportion to that of the Amazon. In North America alone is there anything approaching to it, where the whole country east of the Mississippi and about the great lakes, is or has been an almost uninterrupted extent of woodland."

The forests of the Amazon are distinguished from those of most countries by the great variety of species of trees composing them. Instead of extensive tracts covered with pines, or oaks, or beeches, we scarcely ever see two individuals of the same species together, except in certain cases, principally among the palms. A great extent of flooded land about the mouth of the Amazon is covered with the Miriti Palms (*Maurititia flexuosa* and *M. vinifera*), and in many places the Assai (*Euterpe edulis*) is almost equally abundant. Generally, however, the same species of tree is repeated only at distant intervals. On a road for ten miles through the forest near Pará, there are only two specimens of the Masserandúba, or Cow-tree, and all through the adjoining district they are equally scarce. The *Leguminosæ* are by far the most abundant species among the forest-trees of the Amazon.

The following list of the principal vegetable productions of the Amazon forests is given by Mr. Wallace:—"India-rubber, from the sap of the *Siphonia elastica*; Brazil-nuts, the seeds of the *Bertholletia excelsa*; Salsaparilha, the roots of *Smilax syphilitica*; Tonquin-beans, the seeds of *Dipteryx odorata*; Puxiri, the fruit of *Nectandrum puchury*; Sassafras oil, tree not known; Andiroba oil, from the fruit of an unknown tree; Crajuru, a red colour prepared from the leaves of *Bignonia chica*; Pitch—exudes from a forest tree; *Cacao*, the seeds of *Theobroma cacao* and other species; Cravo, from an unknown tree; Canella, the bark of *Canella alba*; Vanilla, the fruits of various species of *Vanilla*; Guaramá, a preparation from a fruit, grated in water, to form an agreeable and medicinal drink; Piassába, the fibres from the petioles of a palm, *Leopoldinia*, n.s.; *Balsam Capivi*, from the *Copaifera officinalis*; Silk-cotton, from various species of *Bombax*."

From the above rapid sketch of the forest-lands of the globe, it appears that they still cover a great portion of its surface, nor can it be doubted that the immense tracts of wood we have enumerated exercise a very powerful influence on the physical economy of the earth. This influence is both direct and indirect. The direct influence of forests is the diminution of temperature, effected, according to Humboldt,—"1, By screening the soil from the heat of the sun's direct rays; 2, by the powerful evaporation of moisture from the leaves; and 3, by the immense surface which these same leaves offer to the cooling process of radiation."

The indirect influence is the preservation of that due circulation of moisture by which the fertilising rivers of the earth's surface are furnished with a perennial supply of water. Such, indeed, is the importance of forests in this respect, that if it were possible to annihilate at once all the forests that now exist, the earth would no longer be habitable. The rains which fall in the mountains, no longer arrested by the trunks and roots of the trees, would not have time to percolate through the soil and fissures of the rocks to supply the reservoirs of springs, but would pour down in devastating torrents, leaving the watercourses dry as soon as the rain had ceased. This, in a limited degree, has been already experienced in places where the heights have been partially denuded of their forests; and its effect on the rivers in some parts of the United States, where the portion of cleared land is considerable, is distinctly observed. Nor would this be all: lakes, for want of supply, would soon be dried up; and as no waters but those of the ocean would then exist, the atmosphere would then be deficient in moisture; no vegetation could exist, and the animal world would perish of thirst, hunger, and heat. Forests, then, are of primary importance in the economy of the globe, independent of their utility in a thousand arts which are necessary now to our comfort. This consideration has at length awakened governments to the necessity of protecting forests from wanton spoliation by codes enacted for the purpose, and of forming schools in which all that is necessary to be known for the management of forests, so as to maintain a constant supply of timber and fuel, shall be regularly taught. [FOREST SCIENCE.]

FOREST LAWS. In this country even in the time of the Saxons the crown lands consisted in part of forests, or tracts more or less covered with wood, in which the king was accustomed to take the diversion of hunting, and from hunting in which all other persons were prohibited. This distinctly appears from the laws of Canute. But the prohibition against hunting in the royal forests was merely a protection thrown around the property of the crown of the same kind with that afforded to all other landed estates, in regard to which, universally, the law was, that every proprietor might hunt in his own woods or fields, but that no other person might do so without his leave. On the establishment, however, of the Norman government the property of all animals of chase throughout the kingdom was held to be vested in the crown, and no person without the express licence of the crown was allowed to hunt even upon his own estate. This however, is rather a conjecture deduced from the supposed principles of feudalism, than a well-established fact. There are no laws respecting the forests among those attributed to the Conqueror; but after the conquest the forests were guarded with greater strictness; their number was extended and their bounds enlarged; trespasses were punished with greater severity; and, finally, a system of laws and of courts for their administration was established, by which not only all offences touching the royal forests were tried, but all persons living upon these properties governed. This is the system properly called the forest laws. Of this in its original integrity we have no complete or authoritative record: our knowledge is derived from incidental notices of the chroniclers; the energetic language of complaint and condemnation in which it is spoken of; the legislative enactments for its reform which have been preserved; and the remnants of it which survived to a comparatively recent period.

The Conqueror is said to have possessed 68 forests, 13 chases, and 781 parks. Forests and chases differ from parks in not being inclosed by walls or palings, but only encompassed by metes and bounds; and a chase differs from a forest, both in being of much smaller extent (so that there are some chases within forests) and in being capable of being held by a subject, whereas a forest can only be in the hands of the crown. The material distinction was, that forests alone were subject to the forest laws. Every forest however was also a chase. A forest is defined by Manwood, the great authority on the forest laws, as being "a certain territory or circuit of woody grounds and pastures, known in its bounds, and privileged, for the peaceable being and abiding of wild beasts, and fowls of forest, chase, and warren, to be under the king's protection for his princely delight; replenished with beasts of venery or chase, and great coverts of vert for succour of the said beasts; for preservation whereof there are particular laws, privileges, and officers belonging thereunto." The beasts of park or chase, according to Coke, are properly the buck, the doe, the fox, the marten, and the roe; but the term in a wider sense comprehends all the beasts of the forest. Beasts of warren are such as hares, conies, and roes; fowls of warren, such as the partridge, quail, rail, pheasant, woodcock, mallard, heron, &c. He afterwards however quotes a decision of the justices and the king's council that roes are not beasts of the forest, because they put to flight other wild beasts (eo quod fugant alias feras), which seems an odd reason; perhaps the word should be "fugiunt" (because they fly from other wild beasts). And he adds, "beasts of forests be properly hart, hind, buck, hare, boar, and wolf; but legally all wild beasts of venery." ('Co. Litt., sec. 387.)

For the antiquity of the royal forests in England, "the best and surest argument," says Coke, elsewhere (4 'Inst.' 319), "is, that the forests in England, being sixty-nine in number, except the New Forest, in Hampshire, erected by William the Conqueror, and Hampton Court Forest, by Henry VIII., and by authority of parliament, are so ancient, as no record or history doth make any mention of their history or beginning." Yet it appears, both from the great charter of John, and from a previous charter granted by Stephen, that some lands had been afforested (as the term was) after the time of the first two Norman kings. "The forests," says Stephen, "which King William my grandfather, and William II. my uncle, made and held, I reserve to myself; all the others which King Henry superadded I render up and concede in quiet to the churches and the kingdom." And one of the concessions demanded from John and granted in Magna Charta (§ 47) was, that all the lands which had been afforested in his time should be immediately deafforested. No additional forests appear to have been made from the reign of John till that of Hampton Court was constituted by act of parliament in 1539 (31 Hen. VIII. c. 5). The name given to it in the statute is Hampton Court Chase; but it is enacted that all offenders in it shall incur such penalties as the like offenders do in any other forest or chase. It was therefore made a forest as well as a chase.

Many historians tell us that King John granted a charter of forests at the same time with Magna Charta. This is indeed distinctly asserted by Matthew Paris, who even professes to give the charter at full length. But the statement is entirely unfounded; the concessions obtained from John in regard to the royal forests are, as mentioned above, contained in the Great Charter; the Carta de Foresta, which M. Paris quotes, is a charter granted by Henry III. in the 9th year of his reign (A.D. 1224). This was the first separate charter of forests. It is commonly printed in the statutes from the Inspeximus, or confirmation of it, in the 28th of Edward I. (A. D. 1299). The subsequent legislation upon this subject is principally to be found in the following statutes:—The Customs and Assize of the Forest, or the Articles of Attachments of the Forests (of which the date is not known); the Ordinatio Forestæ of the 33 Edw. I. (1305); the Ordinatio Forestæ of the 34 Edw. I. (1306); the 1 Edw. III. c. 8 (1327); and the 7 Ric. II. c. 3 (1383).

One of the chief things insisted upon in the early national demand for the reform of the forest laws, was the mitigation of their severe code of punishments. The Conqueror, who, as the 'Saxon Chronicle' says, loved the red deer as if he had been their father, is affirmed to have visited the slaughter of one of these animals with a heavier penalty than the murder of a human being. And it would appear from the charter of Henry III. that the offence had previously been punishable not only with mutilation, but with death. "No man from henceforth," says the charter, "shall lose either life or member for killing of our deer; but if any man be taken and convict for taking of our venison, he shall make a grievous fine, if he have anything whereof; and if he have nothing to lose, he shall be imprisoned a year and a day and after the year and a day expired, if he can find sufficient sureties, he shall be delivered; and if not, he shall abjure the realm of England." According to Matthew Paris (whose authority, however, on such a matter, is not worth much), Richard I. had already repealed the penalties of mutilation for offences against the forest laws.

The forest laws, as already mentioned, were administered by their own officers and courts. The officers were the justices in eyre of the forest [EYRE]; the wardens or warders; the verderers, foresters, agisters, regarders, keepers, bailiffs, beadles, &c. The courts were:—1. The Court of Woodmote, or of Attachments, sometimes called the Forty Days' Court, held once in every forty days before the verderers; 2. The Court of Swainmote, held three times in the year before the verderers as judges, and with a jury composed of the *swains*, or freeholders within the forest; and 3. The Court of Justice-seat, which was the supreme court, held every third year before the chief justice in eyre of the forest. This was a court of record, and, at least in later times, it was held that a writ of error lay from it to the Court of King's Bench. With the exception, however, of one said by Roger North in his life of Lord Keeper North to have been held *pro forma* soon after the Restoration, no court of justice-seat has been held since 1632. A minute survey of the forest was also taken every third year by its twelve regarders; and it was upon this occasion, and under the inspection of the regarders, that the lawing or expeditation of all the mastifs in the forest took place, which consisted in cutting off the claws and ball (or pelote) of their forefeet, to prevent them from running after the deer.

The four principal forests in England were accounted to be, the New Forest, Sherwood, Dean, and Windsor. Among the others were Epping, in Essex; Dartmoor, in Devonshire; Wichwood, in Oxfordshire; Salcey, Whittlebury, and Rockingham, in Northamptonshire; Waltham, in Lincolnshire; Richmond, in Yorkshire, &c.

The vexatious and oppressive powers vested in the crown by the forest laws, after having to a great extent long ceased to be exercised, were revived by Charles I., and endeavoured to be turned to account in replenishing his exchequer. At the court of justice-seat, held in 1632, before the Earl of Holland as chief justice in eyre south of the Trent, large sums of money were extorted from many persons, chiefly as compositions for alleged encroachments on the ancient boundaries of the forests, although after a quiet possession of three or four centuries. This accordingly was one of the grievances to which the Long Parliament directed its earliest attention. One of the Acts which that assembly passed in its first session (16 Car. I. c. 16), was entitled 'An Act for the Certainty of Forests, and of the Meets, Meers, Limits, and Bounds of the Forests,' and it enacted that the bounds of every forest shall be those commonly known, reputed, used, or taken to be its bounds; and that all judgments, &c., to the contrary shall be void; that no place where no justice-seat or other forest court had been held within sixty years should be accounted forest; and that commissions should be issued for ascertaining the bounds of forests as they stood in the 20th year of the preceding reign, and beyond which they should not thenceforth be extended. Since the passing of this Act, the old forest laws may be considered as having been practically abolished, and the offices connected with their administration and execution turned into little better than sinecures.

The Carta Forestæ of Henry III. contains the following curious provision:—"Whatsoever archbishop, bishop, earl, or baron, coming to us at our commandment, passeth by our forest, it shall be lawful for him to take and kill one or two of our deer, by view of our forester, if he be present; or else he shall cause one to blow an horn for him, that he seem not to steal our deer; and likewise they shall do returning from us as it is aforesaid." As this law is still unrepealed, any bishop or nobleman may shoot one or two of the deer if he should pass through any of the royal forests in going to or returning from parliament. Hunting, it may be observed, was formerly so common or universal an episcopal amusement, that the crown is still entitled, at the death of every bishop, to have his kennel of hounds, or a composition in lieu thereof. Auckland Park, and certain other demesnes, formerly held of the Bishop of Durham by forest services; "particularly," says Camden, "upon his great huntings, the tenants in these parts were bound to set up for him a field-house, or tabernacle, with a chapel, and manners of rooms and offices; as also to furnish him with dogs and horses, and to carry his provision, and to attend him during his stay for the supply of all conveniences. But now all services of this kind are either let fall by disuse, or changed into pecuniary payments." [Game Laws; Woods and Forests.]

FOREST SCIENCE, constitutes a separate and distinct branch of education, which orignated in Germany from the increased scarcity of wood. The first special instruction of this kind was given by Mr. Zanthier at Ilsenburg, near the Harz forest, and its importance being immediately appreciated, forest academies soon multiplied, particularly in the central parts of the country. Prussia directed particular attention to the subject, and the late king Frederick, on coming to the throne, ordered that, "in future, situations in the forest department should be conferred with a view to the most perfect preservation of the forests; that the nominations should be founded on knowledge and experience, and no longer granted as a recompense for service." In consequence a new organisation took place, and competent instruction in all things appertaining to the management of forests became a necessary qualification for an appointment to any post in the forest department.

In the forest academies are taught botany generally, and particularly as regards the ordinary productions of the forest, including vegetable physiology, mineralogy, zoology, chemistry, surveying, mensuration, mechanics, the methods of resisting the encroachments of sands, draining and embanking, together with the care and chase of game; as also the laws and regulations of forest administration. The examination which the candidates undergo is very strict, and the result of the system has been eminently beneficial.

France has also a particular administration of the forests, and a very detailed code of forest laws. Russia, from the immense extent of its forests, is under little apprehension of a scarcity of wood, nevertheless the consumption of this article is so enormous, all the houses of the peasantry being built of it, and no other fuel being used, that it has been deemed advisable to pay some attention to the subject, and a board has been formed under the particular sanction of the government for the better preservation of the forests and more general instruction in forest science.

Louis XIV., by an *ordonnance* of 1669, placed the forests under the direction of a separate branch of the government. Men of science then began to turn their attention to this subject. Du Hamel du Monceau and Buffon were among the first naturalists who wrote on the management of forest trees.

The consideration of the various trees which may be cultivated to advantage, and the uses to which their woods may be put, with the mode of their propagation in various soils, form a branch of forest science.

The following is a list of the principal forest trees:—

The oak *Quercus*), and its varieties, the beech (*Fagus sylvatica*), the hornbeam (*Carpinus betulus*), the birch (*Betula alba*), the elm (*Ulmus*), the maple (*Acer campestre*), the alder (*Betula alnus*), the ash (*Fraxinus excelsior*), the lime (*Tilia sylvestris*), the chestnut (*Fagus castanea*), the walnut (*Juglans regia*), the crab (*Pyrus malus*), the wild cherry (*Prunus avium*), the mountain service (*Sorbus aucuparia*), the service (*Sorbus domestica*), the aspin (*Populus tremula*), the white poplar (*Populus alba*), the common poplar (*Populus nigra*), the Lombardy poplar (*Populus fastigiata*), the sycamore (*Acer pseudo-platanus*), the plane (*Acer platanoides*), the hazel (*Corylus sylvestris*), the sallow (*Salix caprœa*), the osier (*Salix viminalis*), the pine (*Pinus sylvestris*), the silver fir (*Pinus picea*), the larch (*Larix Europea*). The wood of all those trees is divided into three sorts: hard wood, white wood, resinous wood. The German writers admit only two sorts of trees, the deciduous and evergreen, but this is more a botanical division than one applicable to forest-trees.

The uses to which the wood is applied vary very much, according to circumstances and situations. The most profitable is that of timber for buildings, and more particularly for naval architecture. The oak, beech, elm, and fir, are the chief woods employed for this purpose; but the chesnut was at one time considered as equal to the oak, as the roofs and beams of many old buildings testify; Windsor castle among the rest. For millwrights the ash, beech, service tree, walnut, and crab, are most useful. For various utensils for the dairy and domestic use, the sycamore, the lime, and the poplar, are used on account of the whiteness of their wood. Various soft woods are used for turning, as well as the hardest, when they have a close grain and are not apt to split.

When wood cannot be applied to building or domestic uses it is still very valuable as fuel, and in this point of view it is important in those countries where pit coal is not abundant. The best wood for fuel is oak, and next to this beech. The harder the wood, in general, the more heat it gives out in burning. The trunks of large trees, sawn into convenient lengths and then split into billets, make the best fuel; but where wood is scarce it is found most profitable to cut down the trees at the age of 30 or 40 years at most, when they have acquired a considerable height of stem but no great girth. In the woods which are planted for this purpose in France and Germany the trees are drawn up by being left close together, and the side branches are kept cut to the height of 30 or 40 feet, so that they only spread out at top, and the trunk never acquires the size which it would if the tree stood singly, and had room to spread out its branches.

In order to judge of the value of woods in different soils the following table may be useful. It is calculated on the supposition that the ground is covered with trees as much as it will bear.

The cord here alluded to is 5 feet 6 inches in height, 8 feet long and 3 feet 6 inches wide, French measure, that is very nearly 6 feet high 8 feet 8 inches long, and 3 feet 10 inches wide, or 200 cubic feet English measure.

In the following table the tops made into charcoal and the faggots are reduced to cords in the proportion of four and a half cords of charcoal-wood and 550 faggots for one cord of fire-wood.

Produce of Fire-wood per Acre, at different Ages, in Cords.

Age of Trees. Years.	On Poor Soils.	Middling Soils.	Good Soils.
10	2	3½	4½
15	2¼	5¾	9
20	3¾	9¼	15
25	5¼	13¼	21
30	6½	16¾	27
35	7	21	35
40	7	24½	42
50	6	31	56
60	5	37½	70
70	3	41½	80
80	2	46	90
90	1	48½	96
100	..	51	102
120	..	57	114
140	..	62	124
150	..	64	128
200	..	67	135
250	..	60	120
300	..	55	110

This table is the result of careful measurement of woods cut down at different ages; and it shows that the maximum in poor soils is attained in 35 years, in middling and good soils at 200. But it also shows that the increase of wood per cent. in ten years is greatest from 20 to 30 in poor soils, from 40 to 50 in middling soils, and from 70 to 80 in good soils: so that it never can be profitable to allow any wood which is to be used for fuel to stand above 80 years.

In good soils at thirty-five years growth the wood in the tree has increased one cord per acre each year; and the rate of growth increases till the nineteenth year, after which it begins to diminish. But it must also be taken into the account that wood of the age of 70, 80, and 90 years is of far greater specific gravity than that of 25 or 30; and consequently the increase in bulk in ten years, from 80 to 90, produces more fuel than the mere measure indicates. On good soils oaks and beech will continue to increase for 200 years; but in poor soils they do not thrive after thirty-five years, and then they begin to waste.

Preparatory to making a plantation of any extent it is necessary to establish a nursery to raise plants; for although trees which are raised from seed and have never been moved become much larger and finer than those which are transplanted, it will be found on calculation that a quick return is much more profitable; and as a matter of economy trees which have been raised in a nursery and transplanted arrive sooner at a certain growth than those which are sown on the spot where they are to remain.

The ground chosen for a nursery should not have a better soil than that in which the plants are finally to be placed, because, in that case, they would most likely suffer, if not perish altogether. The surface may be enriched by some manure to make the seed vegetate. If it is small, it may be sown in drills, and the acorns and larger seeds may be dibbled regularly as beans are in a garden. The ground being kept very free from weeds by hoeing, the plants will rise regularly, and they may be thinned out after the first year; those which are taken out may be transplanted after cutting off the tap-root, in another spot in the nursery. When the trees are three or four years old, and have clean and straight stems, the side branches having been carefully pruned off, they may be transplanted where they are to remain. The ground should be trenched and well drained if it is wet. It is useful in northern climates to plant hardy evergreens, such as the Scotch fir, amongst forest trees, to serve as shelter to them while they are tender. These are called nurses, and are generally cut out, as the oaks, ash, beech, and other more valuable trees grow up. If the ground is dry it is only necessary to dig a hole eighteen inches deep and a yard in diameter, for each tree; this is to be half filled up with the loose earth taken out; the young tree is then to be placed on this surface and its roots spread out, the tap-root being cut off. The best earth is then carefully spread over the roots and trod in with the feet, and the whole filled up to the level of the ground. In wet situations the trees are sometimes placed nearly on the surface of the ground, and a small mound of earth is raised round the stem; but it is much better to drain the land properly, without which the plantations will never thrive. The proper distance to plant oaks is ten feet apart each way with a fir-tree between every two. In five years half of the firs may be cut out, and the oaks pruned where it is necessary. In fifteen years all the firs will be cut out and the oaks will be able to protect one another. In twenty-five years from transplanting, half of the trees may be cut down, and the remainder thinned out gradually as they spread and advance in growth.

In England, where crooked pieces of large oaks are of value in ship-building, the side branches are not taken off higher than fifteen or twenty feet from the ground; and where trees have plenty of room, as in hedge-rows or parks, this may be judicious, but in close plantations it is of advantage to have a long stem without branches. Knee-timber, as it is termed, is however now much less in demand than formerly, on account of the method adopted of artificially bending straight timber for purposes of naval construction. In France and Germany the branches are always cut off to the height of thirty or forty feet. This is done gradually as the tree grows. When the branch is very young it may be cut close to the tree, and the bark will soon cover the wood and obliterate the scar. When they are larger, it is best to shorten them to a few inches from the stem the first year, and cut them close the next: when a branch is cut close in a young tree no portion of it must project beyond the wood of the stem, and if a portion of the bark of the latter is cut to make all smooth, it will be no detriment, and the wound will soon heal over provided it is done at the proper time. But if a large branch is cut so that the bark cannot grow over the wound in one year, there is great danger of causing a fault in the wood by the decay of the heart of the branch; in that case it is better to cut it at some distance from the trunk, and to shorten it repeatedly till the branch dies naturally and breaks off. In that case no flaw will be found in the wood. This is the operation of nature in a close wood, which we should endeavour to imitate.

FORESTALLING was, like engrossing, an offence at common law against trade. It is described in 5 & 6 Edw. VI. c. 14, to be the buying or contracting for any merchandise or victual coming in the way to market; or dissuading persons from bringing their goods or provisions there, or persuading them to enhance the price when there, any of which practices were supposed to make the market dearer to the fair trader. The prohibition seems to have been derived from the Roman law, which imposed a penalty of twenty pieces of gold in such cases. ('Dig.' 48, tit. 12. 2.)

The true principles of trade being now better understood, forestalling is no longer an offence.

FORFEITURE, the punishment by loss of lands, estates, rights, offices, or personal effects, annexed by law to certain crimes, and also to certain illegal acts or negligence in the holder of lands or offices.

In criminal cases forfeiture is threefold:—1. Of real estates absolutely, as for high treason; if freehold, to the king; if copyhold, to the lord. 2. Of the profits of the real estate, if freehold, to the crown during the life of the offender, and a year and a day afterwards, in the case of petty treason or murder [FELONY], after which the land escheats to the lord [ESCHEAT]; if it is copyhold, it is at once forfeited to the lord. 3. Of goods and chattels, in felonies of all sorts. Some other cases of forfeiture of land or goods, or both, are established by different statutes, as the statutes of premunire, &c.

Lands are forfeited upon attainder, and not before [ATTAINDER]; goods and chattels, upon conviction. The forfeiture of lands has relation to the time of the offence committed; the forfeiture of goods and chattels has not, and those only are forfeited which the offender has at the time of his conviction. A *bonâ fide* alienation of his goods and chattels made by a felon or traitor between the commission of the offence and his conviction is therefore valid.

The statute 15 & 16 Vict. c. 3, contains directions for keeping accounts, and for investment and disposition of forfeited property recurring to the queen by virtue of her prerogative.

Forfeiture in civil cases takes place where a tenant of a limited, or, as it is called, a particular estate, grants a larger estate than his own, as where a tenant for life assumes to convey the fee simple. So, if a copyholder commits waste, or refuses to do suit of court, or a lessee impugns the title of his lessor; for in all these cases there is a renunciation of the connection and dependence, which constitute the tenure, and which are an implied condition annexed to every limited estate.

Forfeiture may also be the consequence of the breach of express conditions or covenants between landlord and tenant, or persons connected in tenure; but in cases of forfeiture where compensation can be made for the breach of the condition, a court of equity will compel the party entitled to the forfeiture to accept compensation. The right to take advantage of a forfeiture may also be waived by any act of the person entitled which recognises the continuance of the title in the particular tenancy,—as, for instance, the receipt of rent by a landlord in respect of a time subsequent to the act by which the forfeiture is incurred.

Lands may also be forfeited by alienation contrary to law, as by alienation in mortmain without licence, or to an alien: in the former instance, if the immediate lord of the fee, or the lord paramount, neglect to enter, the crown may; and in the latter, though the conveyance is effectual, yet as an alien cannot hold lands the crown may enter, upon office found. [OFFICE FOUND.]

Offices are forfeited by the neglect or misbehaviour of the holders; and the right to the next presentation to ecclesiastical benefices is forfeited by simony and by lapse. Simony is the corrupt presentation of any one to an ecclesiastical benefice for money, gift, or reward. Lapse is where the patron neglects to present to a benefice within six months after it has become vacant, in which case the right to present accrues to the ordinary; by neglect of the ordinary for the same space of time, to the metropolitan; and by the like neglect of the metropolitan, to the crown. [BENEFICE.]

FORGE; FORGING MACHINE. Many improvements have been introduced in recent years in the apparatus for forging or hammering heated iron. We do not advert here to the marvellous powers of Nasmyth's steam hammer [HAMMER], but to contrivances of a smaller and more generally applicable kind. As is well known, a common smith's forge consists chiefly of a hearth on which the burning fuel is placed, bellows for exciting the intensity of the heat, anvils on which to rest the heated metal while being forged, and hammers and swages to bring the metal into form. An anchorsmith's forge is somewhat similar, but on a larger scale. The recently-invented forges, however, are all intended to effect something more than can be accomplished by the ordinary forge, either in quantity or in kind. We will adduce a few instances.

Richards's forging machine accomplishes all the operations of heating, holding, carrying forward, turning, and hammering the piece of heated metal which is under process. The face of the hammer has a peculiar curved movement, to draw the piece of metal forward; and the swages or shaping dies, carried on the lower side of the hammer, have such forms and positions that the heated metal, placed between them and the anvil, is made to assume a shape successively nearer and nearer to that which is desired.

Chaplin's forge is compact and portable, and gives out an intense heat. An upright iron frame contains the blowing apparatus. A sheet-iron tray is mounted on wheels: and an upright front is attached to the tray by a single bolt. The fuel is contained in a long concave pan of cast-iron, bolted to the frame, the bolts acting as hinges for folding up; and the opposite end of the pan is supported by two standards. An adjustable dead-plate is fitted to the inner front of the frame, to prevent the injurious action of the heat on the blowing-machine. A portable hinged hood is so fitted as to reflect the heat downwards, and carry off the smoke. A cold-water trough is hooked upon the end of the fire-pan. The blowing apparatus consists of small fans placed near the bottom of the frame; it is driven by a band from a pulley on the spindle of a winch-handle: or, in another arrangement, a treadle is used instead of a winch, thereby leaving the hand at liberty. This ingenious arrangement of parts would render the forge available as a shot-heater, or for melting small quantities of iron or brass; for the latter purpose, the fire-pan is superseded by a cupola lined with fire-clay. So intense is the heat produced in this forge, that a bar of iron an inch and a half in diameter can be brought to a welding temperature in four minutes.

Hattersley's forging machine comprises such an arrangement of swages, dies, or hammers, as effects great saving of time, and enables the forging to be finished in one heat. There is a rapid mode of transferring the bars of heated iron from one pair of swages to another.

Ryder's machine consists of a series of hammers, or vertical stampers, so varied in shape as gradually to forge the heated metal into the desired form. The patent for this machine expired in 1855, and application was made for a renewal, on the ground that the invention had only become profitable when the patent was nearly out; but this application was refused.

The last which we shall notice is Campbell's steam-forge, which combines both a blowing and a striking apparatus. It is worked by a small steam-engine, which obtains its steam partly by the action of the forge fire. There is a small horizontal steam-cylinder attached to the frame which carries the forge-hearth, and connected with the frame is a system of shafts, speed-wheels, pinions, &c., to move the piece of metal which is to be acted on, and also the hammer. There is a blowing-fan making sixteen hundred revolutions in a minute. The boiler for the steam-engine is over the hearth. The forge-anvil is placed by itself on the floor, at the other end of the machine. The hammers are attached to levers on a horizontal shaft in the hearth-frame, and are set in motion by the steam cylinder, through the medium of a long sliding rod which strikes the tail of the lever or levers. Hand-gear is provided for working the hammers if steam-power should not be available.

FORGERY is the false making, counterfeiting, altering, or uttering any instrument or writing with a fraudulent intent, whereby another may be defrauded. The offence is complete by the making the forged instrument with a fraudulent intent though it be not published or uttered, and the publishing or uttering of the instrument, knowing it to be forged, is punished in the same manner as the making or counterfeiting.

It is by no means necessary to bring the offence within the legal meaning of the term forgery, that the name of any person should be counterfeited, though this is the most common mode in which the crime is committed; thus a man is guilty of forgery who antedates a deed for the purpose of defrauding other parties, though he signs his own name to the instrument; and the offence is equally complete, if a man being instructed to make the will of another, inserts provisions of his own authority. In truth the offence consists in the fraud and deceit.

At common law the crime of forgery was only a misdemeanour, but as the commerce of the country increased and paper credit became proportionally extended, many severe laws were enacted, which in most cases made the offence a capital felony.

The extreme severity of these laws tended to defeat their object, and parties very frequently chose rather quietly to sustain the loss inflicted upon them by the commission of the offence, than by a prosecution to subject the offender to the loss of life. This feeling, and the diffusion of the truth, that the object of all laws is to prevent crime and not merely to punish, has caused successive mitigations in the laws relating to forgery, and now by various statutes, particularly the 11 Geo. IV., and 1 Will. IV. c. 66; 2 & 3 Will. IV. c. 59, and 1 Vict. c. 84, the punishment of death is abolished in cases of forgery, and a punishment varying between transportation for life (now penal servitude) and imprisonment for one year is substituted.

(1 Hawk, P. C.: Russell *on Crime;* Deacon's *Criminal Law.*)

FORK (Anglo-Saxon *forc;* the same as the Latin *furca*), an instrument divided at the end into two or more prongs for various uses, especially for the table. Addison speaks of a thunderbolt with three forks. It is sometimes used for an arrow, and in old English for a gallows or gibbet. Butler, in his 'Remains' (ii. 195), says, "They had run through all punishments, and just 'scaped the *fork*." The furca was an instrument of punishment among the Romans. Criminals convicted of serious crimes were fastened to it and then scourged to death; but it was also used for slighter punishments, and for some offences slaves were condemned always to carry it about with them: hence the use of the word "furcifer" as a term of reproach.

The agricultural or dung-fork, and a large fork for the flesh-pot, were the only implements of this name apparently in use among our early ancestors. The first mention of table or eating forks is probably found in the 'Chronicon Placentinum' of John de Mussis ('Muratori,' vol. xvi., p. 584), a writer of the early part of the 15th century, who, when speaking of the luxuries of the people of Piacenza recently introduced, says, "they use cups, and spoons, and *little forks* of silver" ("et utuntur taciis, cugiariis, et *forcellis* argenti"). But the fork must have been in use in some parts of Italy some centuries earlier, if Alberti ('Urbis Venetæ Descriptio,' Venice, 1626, p. 221) be correct in asserting that it was regarded as a mark of pride in the wife of the Doge Domenico Silvio, who flourished towards the close of the 11th century, that she would not use her fingers, but employed a fork in eating ("cibum non digitis sed *furcillis* aureis caperet"). Coryate, in his 'Crudities' (edit. 1611, p. 90), announces himself as the person who introduced this Italian fashion into England. He says, "Here I will mention a thing that might have been spoken of before, in discourse of the first Italian town. I observed a custom in all those Italian cities and towns through the which I passed, that is not used in any other country that I saw in my travels; neither do I think that any other nation of Christendom doth use it, but only Italy. The Italian, and also most strangers that are commorant in Italy, do always at their meals use a little fork when they cut their meat. For while with their knife, which they hold in one hand, they cut the meat out of the dish, they fasten their fork, which they hold in their other hand, upon the same dish, so that whatsoever he be that, sitting in the company of any others at meal, should unadvisedly touch the dish of meat with his fingers from which all at the table do cut, he will give occasion of offence unto the company, as having transgressed the laws of good manners, insomuch that for his error he shall be at the least browbeaten, if not reprehended in words. This form of feeding, I understand, is generally used in all places of Italy, their forks being, for the most part, made of iron or steel, and some of silver, but those are used only by gentlemen. The reason of this their curiosity is, because the Italian cannot by any means endure to have his dish touched with fingers, seeing all men's fingers are not alike clean. Hereupon I myself thought good to imitate the Italian fashion by this forked cutting of meat, not only while I was in Italy, but also in Germany, and oftentimes in England since I came home: being once quipped for that frequent using of my fork, by a certain learned gentleman, a familiar friend of mine, one M. Laurence Whitaker, who, in his merry humour, doubted not to call me at table *furcifer*, only for using a fork at feeding, but for no other cause." Coryate's testimony is confirmed by Fynes Morison, in his 'Itinerary' (P. i., p. 208, fol., 1617), who, speaking of his bargain with the patron of the vessel which conveyed him from Venice to Constantinople, says, "he gave us good diet, serving each man with his knife, a spoon, and a fork." Ben Jonson, in 'The Divell is an Asse' (act v. sc. 4), makes Mere-Craft speak of his "pains at court" to get a patent for his "project" for "the laudable use of forks, brought into custom here as they are in Italy, to the sparing of napkins;" and that they are to be "of gold and silver for the better personages, and of steel for the common sort." See also his 'Volpone,' act. iv. sc. 1.

Even when Heylin published his 'Cosmography,' in 1652, forks for the table were still a novelty: see his third book, where, having spoken of the ivory sticks used by the Chinese, he adds, "the use of silver forks with us by some of our spruce gallants taken up of late, came from hence into Italy, and from thence into England."

FORM. Everything that exists may collectively be termed the "something," in opposition to the "nothing." This "something" divides itself into four great divisions, namely, things, ideas, forms, and appearances. Form is the manner and mode in which a thing is presented to our conceptions. Things are of two descriptions: immaterial, as faculties and intellect; and material, as matter and bodies. The forms of the immaterial things are called categories; the forms of the material we may call figures; the form of appearances retains the name of form; and ideas are formless. The categories, according to the opinion of the writer (founded upon those of Aristotle, Kant, and many others), are the following:—1. Categories of position,—to be, not to be, and to become; 2. Categories of quality,—substance, accident, and mode; 3. Categories of relation,—cause, effect, and action and reaction; 4. Categories of quantity,—universality, multiplicity, and unity. The logical categories are possibility, actuality, and necessity. [CATEGORY.] The figures, on account of their variety, do not admit of being classified, yet we may divide them according to the senses, into shapes, colours, sounds, smells, and tastes, and into the different modes of feeling.

Form is distinguished from the real nature of things, and, considered in this point of view, the idea of form is practically used in common speech and in science. Thus we speak of a form of law, a form of government, a beautiful form, a logical form, &c. Whoever esteems the form of anything more highly than the thing itself, or through narrow-mindedness confounds the one with the other, is a formalist, as many learned men and official persons are.

FORMÂ PAUPERIS. By stat. 11 Hen. VII. every poor person shall have original writs or subpœnas, without paying for writing or sealing the same; and the judges of all courts of record, where such suit shall be carried on, are authorised to assign clerks to write, and counsel and attorney to act for such person, without taking any reward. It is discretionary with the court to grant this indulgence, but it is rarely refused upon petition, supported by affidavit that the petitioner is not worth 5*l.* in the world after paying his just debts, exclusive of his wearing apparel, and the right to the matter in controversy, and by a certificate by a barrister that he has good cause of action or suit. The Court of Chancery has from an early period permitted parties to sue and defend as paupers upon the same conditions as the courts of law, though in that court, it seems, if the party be in possession of the subject matter in dispute, and that should be worth more than 5*l.*, he cannot except it in his affidavit, and therefore will not be regarded as a pauper. The privilege may be granted either at the commencement of the suit, or at any period of its progress, but if granted during the pendency of the suit, it has no retrospective effect, and the party is not relieved from the costs previously incurred.

A person allowed to sue *in formâ pauperis* pays neither for stamps, nor fees to the officers of the court, but if he obtains a verdict with damages above 5*l.*, the officers take the fees. In case of improper or vexatious conduct on the part of the pauper, the courts will deprive him of the privilege, which is called dispaupering him; but it seems that in such cases a pauper plaintiff is never ordered to pay costs to the defendant, though, according to Blackstone, a pauper, if non-suited in his action, formerly had his election either to be whipped or pay costs.

FORMEDON (a compound of the two Latin words *formam doni*), one of the many writs in use under the old law for commencing a real action, before the more convenient mode of trying titles to land by ejectment was established. [EJECTMENT.] It was the peculiar remedy of a tenant in tail, who claimed *per formam doni*, and the highest he could have, and was therefore called tenant in tail's writ of right. The writ of right was granted to such only as claimed the fee simple, for which reason the statute *De Donis* (Westm. 2, 13 Ed. I.) gave this writ to tenants in tail. Together with all the others used for the commencement of real actions, it was abolished by stat. 3 & 4 Will. IV c. 27, s. 36.

FORMEN. [Methyl, *Hydride of.*]

FORMIC ACID. [Formyl.]

FORMIC ETHER. [Formyl.]

FORMULÆ, CHEMICAL. [Chemical Formulæ.]

FORMYL. This name was originally applied to a hypothetical radical (C_2H) supposed to be contained in formic acid, chloroform, and other bodies, but it is now exclusively used to denote the oxygenous radical of formic acid $\left(\begin{matrix}C_2HO_2\\C_2HO_2\end{matrix}\right\}\Big)$. This radical is unknown in a separate condition, but in combination with oxygen and water it constitutes—

Formic acid, C_2HO_3HO, which originally obtained its name from having been found present in the red ant (*Formica rufa*). Hence also the name of the radical formyl. This acid may be procured from methylic alcohol, $C_2H_3O + HO$, by the loss of two equivalents of hydrogen, and the addition of two of oxygen. It may also be procured by mixing starch or sugar with peroxide of manganese, water, and sulphuric acid, and distilling. It is formed also under a great variety of other circumstances. It unites with lead, forming a formiate of lead, and from this, formiate of soda may be procured by the addition of carbonate of soda. It unites freely with most of the metallic oxides, and many of the salts when heated in closed vessels give off carbonic acid and carbonic oxide, leaving the pure metal. It unites also with ammonia, the salt thus formed containing the elements of hydrocyanic acid and water.

It is the first or lowest member of the important series of Fatty Acids. Formyl also enters into the composition of the following compounds:—

Formic ether $\left(\begin{matrix}C_2HO_2\\C_4H_5\end{matrix}\right\}O_2\Big)$ may be obtained by distilling a mixture of formic acid and alcohol; but it is much better procured by distilling a mixture of 10 parts of concentrated sulphuric acid, 7 of formiate of soda, and 6 of alcohol. The distilled product should be mixed with water to separate the alcohol which it contains, then agitated with magnesia to saturate any excess of acid, and lastly, freed from water by distillation with chloride of calcium. This is Döbereiner's process.

Formic ether is a colourless liquid, of a strong odour, resembling that of peach kernels; its taste is peculiar. Its sp. gr. is 0·915 at 65°, and it boils at 132° Fahr. It mixes with alcohol in all proportions; but water takes up only ⅑th of its weight; and after some time the solution is found to be converted into a mixture of alcohol and weak formic acid: this ether burns in the air with a blue flame, the edges and point of which are of a bright yellow.

Formobenzöilic acid ($C_{32}H_{16}O_{12}$). A composite acid, which stands in the same relation to the benzoic series as lactic acid does to the acetic series.

Formanilide, Phenyl-formiamide ($C_{14}H_7NO_2$). One of the products of the action of heat upon oxalate of aniline. [Anilides.]

FORMYLIA. An organic base so-named by Clöez, but which has since been proved by Hofmann to be *ethylene-diamine* ($N_2C_4H''_4H_4$). It is formed by the action of bi-bromide of ethylene upon ammonia.

FORNAX (Constellation), the Chemist's Furnace, one of the southern constellations of Lacaille. It is situated immediately below Cetus. It does not contain any stars of conspicuous brightness.

FORT is the term applied to any enclosed field work, or small permanent work. It is however often very loosely applied.

FORTE (Italian *strong*, *loud*), a musical term, directing the performer to sing or play loudly, with strength.

Fortissimo is the superlative of *Forte*.

FORTRESS, a fortified city or town, the works of which are such as to require an attack in form, or are capable of resisting an attack de vive force.

FORTIFICATION is the art of constructing works for the protection of a town or military position; the object being to enable a lesser force to be a match for a greater from the advantages of its position. Or, as in the case of offensive fortification, such as siege works, to increase the power of the assailants. Fortification has, therefore, been divided into two parts, *permanent* and *field*, the former comprising such works as are intended to last for many years, and the latter such as are hastily executed for the defence of a position of an army in the field, or the attack of a fortress.

The principles which regulate the general plan of the works constituting the fortifications of a town or great military post, have at all times been nearly the same. Among the ancients, with scarcely any exception, the polygonal wall surrounding a place was provided with towers projecting from it at intervals towards the front; and a barbacan, or outwork, consisting of two or more towers, connected by walls like those of the fortress itself, was generally constructed on the exterior side of the ditch and opposite a gate of the town, in order to protect that entrance and the bridge leading to it. The towers and walls about an ancient town correspond to the bastions and curtains forming the enceinte of a modern fortress, and the barbacan may be considered as the counterpart of its ravelin, or principal outwork.

The necessity which the nations of Europe were under of remodelling their fortified towns in consequence of the change produced in the art of war by the invention of gunpowder, gave occasions for the engineers of Italy, France, and the Netherlands to emulate each other in devising the most advantageous methods of disposing the works for the purposes of defence with relation to the arms then newly introduced; and the result of their labours was the construction of numerous strong fortresses on the frontiers of those countries. In these the bastion system, as it is called, was invariably adopted [Bastion]; and it is remarkable that, of the very numerous projects which have been offered to the world for fortifying places, so few should have been till latterly of a different kind. The variations however which occurred in the details of the plans gave rise to the denominations of the Italian, the French, the Spanish, and the Dutch methods, in speaking of the works proposed or executed at the end of the 16th and the beginning of the 17th centuries; but it must be observed that those variations consisted chiefly in the magnitude of the angle which the two faces of a bastion made with each other, and in the extent of what was called the second flank; that is, the portion of the curtain then generally left between the flank of a bastion and the place where the produced face of the collateral bastion intersected the curtain.

The first bastioned fortresses of France appear to have been very inferior to those which were executed in the Netherlands by the Italian engineers; and there still exist some remains of these last in which the bastions are sufficiently capacious, and at distances from each other within the effective range of musket-shot. The others, on the contrary, were characterised by small bastions, scarcely capable of receiving artillery, and placed so far asunder as to defend each other very imperfectly. But after the termination of the civil wars which desolated the country, the attention of the French government was directed to the state of the military posts; and Errard de Bar le Duc, a member of the corps of engineers then instituted, was appointed to superintend the reparation of the old, and the construction of the new fortifications. The citadel of Amiens was built according to the plan proposed by this officer, who, in 1594, published a treatise on fortification, in which some effort is made to determine the principles which should regulate the forms and dimensions of the works; his method, however, is only a faulty modification of the Italian.

In the method proposed by Errard the bastions are much larger than those of the earlier time, the length of their faces being, as at present, about one-third of the distance between the salient angles of two collateral bastions; an orillon occupied nearly two-thirds of the length of each flank, which was very short, and formed an angle of about 80° with the curtain. This direction appears to have been given to the flanks in order that the guns behind their parapets might be as much as possible concealed from the view of the enemy in his counter-battery; but it is evident that the defenders of the opposite flanks, laying their muskets perpendicularly to the lengths of the parapets, according to the general practice, would almost inevitably, especially in the dark, fire upon each other, or upon those who were stationed on the curtain.

De Ville, who composed a treatise on fortification in 1629, made several improvements on the method proposed by Errard, the principal of which were an augmentation of the length of the flanks and a perpendicular direction of the latter with respect to the curtain: by these changes a better defence was obtained from the flanks, and the evil above mentioned was diminished. But a still greater amelioration was made by Count Pagan, who, in 1645, proposed to make each flank [see the half-front of Fortification between F and G, fig. 1, Bastion] perpendicular to the produced face of the collateral bastion; the reciprocal defence which the works should afford each other is thus complete, and the men are not in danger of being fired on by each other. Pagan retains the orillons at the shoulders of the bastions, and he gives to the latter double or triple flanks; but the construction of these, and of many other works supposed to be modern improvements, such as the demi-revetment, are to be found in Castriotto's work, published in Venice in 1564: they have, however, on account of their numerous inconveniences, ever since been discontinued.

During the reign of Louis XIV. a general reparation or reconstruction of its fortresses was ordered by the French government; and the talents of Vauban, which were exercised in devising and carrying into execution, the strengthening and improving 300 places and the building of 33 new ones, together with the merit displayed in the conduct of fifty-three sieges, have given that engineer so much celebrity. Besides the changes made in the disposition of the parts of the enceinte, the outworks were entirely remodelled; and instead of assigning for the delineation of the plan, numerous arbitrary rules which varied with the nature of the polygon, Vauban adopted the length of the side of the polygon as a base, and took certain aliquot parts of this line for the dimensions of the several divisions of the rampart; thus reducing the construction to a few simple precepts which were applicable to places of all magnitudes. These precepts being founded on the uses of the works may be justly considered as constituting a system of fortification, though many of his works are found in older writers; and from that time to the present scarcely any deviations have been made from them in the construction of great fortresses. A brief outline of the system will therefore be here given. [See the half-front of fortification between G and E, *fig.* 1, Bastion.]

The length of each side, as F E, of a regular polygon supposed to surround the town or position, is made from 320 to 400 yards, say about 380 yards, in order that all the parts of the rampart on each front of the enceinte might be within the range of the arms employed in the defence, but more especially that the faces of the bastions should be within range of the flanks. This for the old smooth-bored musket would have required a range of 180 to 200 yards, but this being impracticable from the relief required in the bastion, and from its further rendering the bastion too small, the length is determined by the range of rifles, wall pieces, and grape shot, which is about 300 yards. Now these being supposed to be placed on the flanks, as at *e* or *f*, might be employed to oppose the formation of the counter-battery at H, or at the corresponding point on the left of F; therefore, if we assume the length of the line from *e* to H to be 300 yards, and deduct from it the estimated breadth of the main ditch and covered-way (40 yards), we have 260 yards for the length of *e* E or *f* F, which is called the line of defence. This is also the distance of E or F from the shoulder of the collateral bastion; and if we add to it the length of the face of the bastion, which is 103 yards, or 2·7ths of E F, in order that, in the inferior polygons, the bastion may have sufficient capacity, we obtain about 380 yards for the distance between the salient points F and E of the two bastions; and it may be observed, that a few yards more or less in the dimensions need not be regarded.

The directions of the faces of the bastions on each front coincide with lines drawn from the angles E and F of the polygon, through the extremity of a perpendicular let fall from the middle of the line E F and made equal to one-sixth of that line; and each flank is the chord of an arc, described either from the opposite angle E or F of the polygon, or from the nearest shoulder of the collateral bastion, as a centre. By this construction the flank is rather greater in length than the enemy's counter-battery, which is necessarily limited by the angle of the glacis and the prolonged face of the nearest bastion; and it is nearly perpendicular to the direction of that face: the reason why it is not made exactly so is, that a man on the flank, placing his musket perpendicular to the line of parapet, will thus be able to fire into and defend a breach which may be made in the face of the collateral bastion. The curtain is determined by a line joining the interior extremities, near *e* and *f* of the flanks; and, with the height which Vauban assigned to the rampart of the enceinte, this length will permit the fire of musketry from each flank to defend the opposite half of the ditch between the flanks. The line which on the plan indicates the directions of the faces, flanks, &c., of the works, is called the magistral line; it forms the exterior side of the ramparts in *fig.* 1 [BASTION], and coincides with the cordon, or projection, at the top of the revetment N, *fig.* 2.

The dimensions of the ditch are determined by the necessity of obtaining from it the earth for the formation of the ramparts and parapets, the depth being fixed by giving the escarp the least height which is considered quite secure from escalade. This for the main works should be about 32 feet, which gives a breadth of ditch at the flanked angles of the bastion of 38 yards. The counterscarp wall is rounded opposite the flanked angles at E or F, and is directed from thence towards the shoulder of the collateral bastion.

The improvements made by Vauban in the ravelin are described under RAVELIN: Q represents one-half of that work; and it will be merely necessary here to say, that its plan is determined by using the angular points near *e* and *f*, formed by the magistral lines of the flanks and curtain, as centres, and with radii equal to the distances from thence to points taken on the faces of the collateral bastions, at 10 yards from their shoulders, describing arcs; the intersection of these arcs determines the salient angle of the ravelin; the magistral lines of its faces tend from that intersection to the points just mentioned, and terminate on the counterscarp of the main ditch.

The traverses in the covered way were proposed by Vauban, in order to diminish the effect of the ricochet fire of the besiegers, which Vauban was the first to employ in the attack, in which he was even more famous than in the defence, being the first to give it that decided superiority which it has ever since maintained, and one of the principal means of which was the ricochet fire. He was the first engineer who formed the spacious places of arms, as they are called, at L, in the re-entering parts of the covered-way, in order to obtain room for assembling troops, and to afford a good crossing fire of musketry from their faces for the defence of the glacis in front of the bastions and ravelins.

An attention to the reliefs of the several ramparts of a fortress is no less necessary than to the plans; for, as it would be advantageous, when the approaches of the besiegers are near the foot of the glacis, that a fire of artillery should be made from the ramparts of the enceinte or ravelin, and of musketry from the covered-way at the same time, the reliefs of those ramparts should be determined by imagining a line to be drawn from the foot of the glacis through a point 3 or 4 feet vertically above the crest of the latter, that is about 11 feet above the ground, and to be produced through the parapet of the said enceinte or ravelin; then, if the soles of the embrasures, which are necessarily 4½ feet below the crest of the parapet, be made to coincide with such imaginary line, the fire of artillery from them may be directed to the enemy's trenches without incommoding the defenders of the covered-way. The crest of the enceinte thus determined will be about 18 feet above the ground, and that of the ravelin about 3 feet less.

The tenaille, P, *fig.* 1 [BASTION], will be described under that word; but it may be mentioned here that the relief of this work is determined by the consideration that, while it should be high enough to mask the postern in the curtain behind it, the men stationed on it to defend the ditch should be below the lines of fire from the flank of one bastion, when directed to the foot of a breach supposed to be made near the shoulder of that which is collateral to it, in order that they may not be injured by that fire.

As Vauban had occasionally to adapt works constructed according to the principles above mentioned, to the old fortifications which then existed, the particular method employed in disposing them acquired the denomination of his second system; and when, subsequently, he fortified Neu Brisach, some few modifications which he was led to make gave rise to a new distinction, the works of that place being considered as forming a third system. In both these systems the bastions V, *fig.* 3 [BASTION], are separated by a ditch from the enceinte; and this circumstance is so far advantageous, that the place would not be compelled to surrender immediately upon those works being taken by the besiegers. The enceinte consists of a long curtain, either quite straight or broken by two short flanks; and at the angles of the polygon are small bastion-towers of masonry (T, *fig.* 3), in whose flanks are formed casemates to contain artillery for the defence of its ditch. This great engineer died in 1707, at the age of 74 years; and, from his time, the French fortification has been to a great extent that of all Europe.

It would be improper in this place to omit the name of Minno, Baron of Coehorn, who was born in the year 1641, the year preceding the birth of Vauban, and who in the service of the United Provinces acquired a reputation scarcely inferior to that of his great rival. In the year 1692 they were directly opposed to one another, Coehorn defending Namur against Vauban, who conducted the attack. His system, or systems, as he in his treatise describes three, are essentially adapted to aquatic sites, such as those of Holland, and he applied them, with the modifications required by the ground, to Nimeguen, Breda, Manheim, Namur, and Bergen-op-Zoom. Tilbury Fort is also on his system. The outline of the plan differs but little from that of his rival's great system, but the shoulders of the bastions are strengthened by large towers, or orillons, containing casemates. In the interior of each bastion is another, on a higher level, and on the exterior is a counterguard, consisting of two faces, parallel to those of the bastion. A large ravelin, inclosing a redoubt on a higher level, is placed before the curtain, and the whole is surrounded by a broad covered-way, whose places of arms are retrenched by brick redoubts. The plane of site of the works is assumed to be 4 feet above the level of the water, which allows the system to combine the advantages of wet and dry ditches. When the wet ditches are employed the expense of the revetment is saved, and the dry ditches which separate the unrevetted portions from the principal works afford the garrison a great advantage in resisting the besieger while defiling from his bridge across the wet ditch to attack the inner works, which have a sufficient revetment to resist an assault without ladders, but are still low enough to be protected from distant fire. The terrepleins, as well of the bastions and ravelins as of the covered-way, are sunk below the natural surface of the ground, so that it would be impossible, in the marshy soil on which the fortifications are supposed to be constructed, for an enemy to dig trenches there in order to form covered approaches. The terrepleins of the principal works are also well defended by fire from the covered galleries which cross them, or which are formed within the masses of the ramparts.

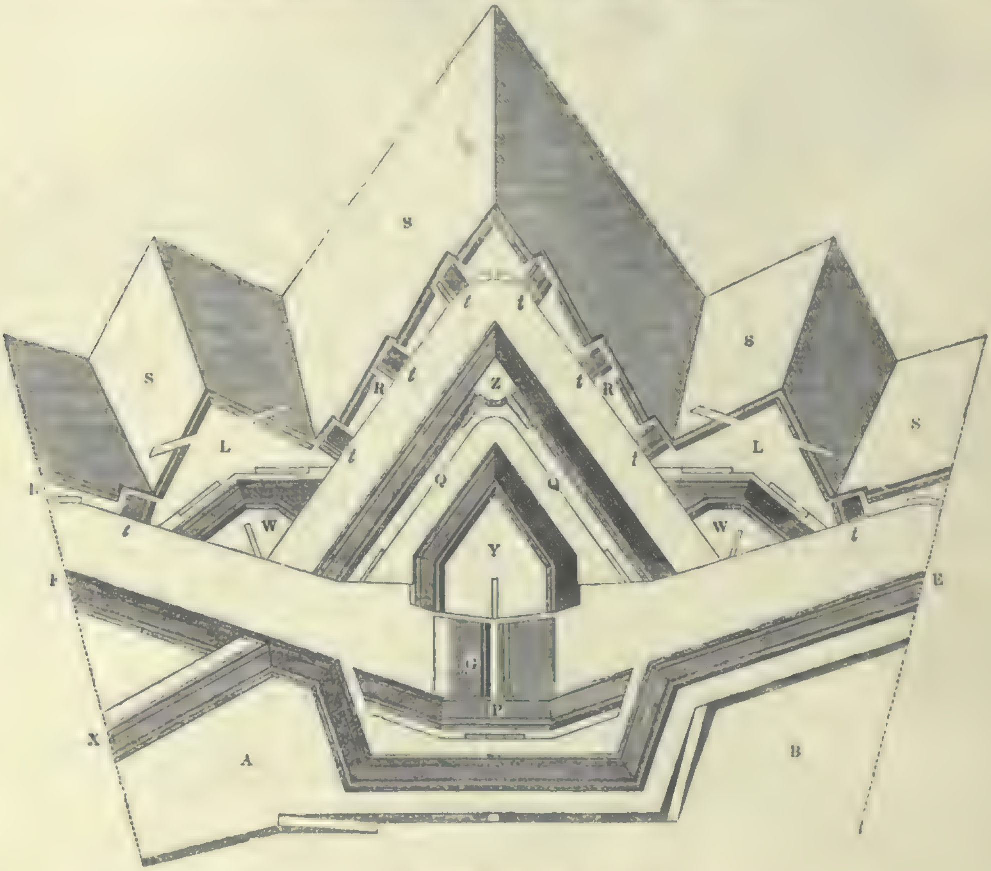
It should be observed that the salient points, E, F, &c., of the bastions and ravelins in Vauban's system being nearly equally distant from the centre of the place, the trench executed by the besiegers to connect the glacis before the former works will also connect that which is before the latter; and that, in consequence of this construction, breaches may be formed, and assaults made, at one time, in the enceinte and outworks. With the view, therefore, of preserving the former untouched till some time after the ravelins may have been taken, the French engineer Cormontaingne proposed, about 30 years after the death of Vauban, to advance the salient points of the ravelins as much as possible, by increasing the length of the faces to the utmost limit which a regard to the due magnitude of the flanked angle will admit. Thus the magistral line of his ravelin is determined by directing its faces on the faces of the collateral bastions, at 22 yards from the shoulders; and its salient or flanked angle by the intersection of the perpendicular produced of an arc described from one of these points as a centre, and the shoulder of the opposite bastion as a radius. By this construction it would become impossible for an enemy to crown the glacis of a bastion till he had got possession of the two collateral ravelins, on account of the fire which, from these, might be made upon his approaches between them; and the fall of the place would be delayed by the time spent in conducting the approaches from the ravelins to the intermediate bastions.

In order that this benefit might be obtained in the highest degree, Cormontaingne suggested the propriety of fortifying places on polygons of the superior kind, and even, when possible, of constructing two or more fronts of fortification on one straight line; this practice would have the additional advantage of rendering the flanked angles of the bastions very obtuse, by which, not only would the increased capacity of those works permit stronger retrenchments to be formed in them, but the faces being produced outwards, would tend to points on the faces of the ravelins, and thus would be completely secured from the enfilading fires of the besiegers.

Besides the above general modifications, Cormontaingne made several improvements in the details of the works. He made the flanks exactly perpendicular to the prolonged faces of the collateral bastions, for the sake of a more complete flanking defence. He made the terrepleins of the ravelins merely wide enough to contain the artillery of the defenders; in order to increase the capacity of the redoubt in the ravelin, and to deprive the enemy of the space necessary for a battery on the ravelin, by which he might breach that redoubt. He also gave large casemated flanks to the latter work, in order that a powerful fire might be directed from them against the enemy, if he should attempt to mount the breach in the face of either bastion before he had got possession of the redoubts as well as of the ravelins themselves. A further improvement was made by this engineer in adding to each of the re-entering places of arms a spacious redoubt, which would render the defence of that place more obstinate, and cover the passage between the tenaille and the flank of the bastion. The following are the commands of the principal works above the country.

Salient of bastion	26½	feet decreasing 1 foot to flank of do.
Salient of redoubt of ravelin . .	24	" "
Salient of ravelin	22	" extremity of face.
Redoubt in Re-entering place of arms	14	
Tenaille	8	
Covered-way	9	

Plan of a Front of Fortification according to the Method of Cormontaingne.



80 yards to an inch.

A. Solid Bastion; B, Hollow ditto; X, Retrenchment; P, Tenaille; G, Caponnière; Q Q, Ravelin; Y, Redoubt in ditto; L L, Re-entering places of Arms; W W, Redoubts in ditto; R R, Covered-way; t t, Traverses; S S, Glacis; E, Barbette battery.

Cormontaingne's system, to which the name of French modern system was for some time applied, has at various times been modified in many of its details, especially by the French engineers at their schools of application (formerly at Mezieres, and now at Metz), and at the present time the term of Modern System is applied to one which may be considered as the most perfect Bastioned trace, and which is taught in the French engineer schools as the normal bastion trace. The proportions given by Cormontaingne to the enceinte are retained with the exception that the flank is increased by directing the escarp of the faces of the bastion to the angle of the flank of the magistral line instead of to the interior crest. The saliency of the ravelin is however still farther increased, and it is in this that the principal modification of the modern system lies, by directing its faces on the faces of the bastion points 36 yards from the shoulders, and giving the salient or flanked angle the greatest saliency possible, allowing it in fact only an opening of 60°, which is the least admissible. The ravelin being thus enlarged allows of a larger redoubt, though the terreplein of the ravelin, which Cormontaingne only considered a species of counterguard, is also increased. A permanent coupure is made across each face of the ravelin at the point where a perpendicular from the extremity of the magistral line of the nearest face of the redoubt of the covered way cuts it in order that the besieger may not by sapping along the face of the ravelin, and thus be able to see into and drive the defenders out of the redoubt. The greater saliency of the ravelin allows of four traverses in the covered way instead of the three, according to Cormontaingne's system.

The modern system however has some important defects, among which the principal are that the ravelin and its covered way present long lines easily enfiladed, and the faces of the bastion may be breached by the besieger firing down the ditch of the ravelin from his breaching battery on the crest of the glacis at its salient, even more easily than in Vauban's first system. The flanks of the bastion also being brought closer together, increase the undefended portion in front of the curtain and tenaille. To remedy these defects, Colonel Dufour has proposed certain modifications. Taking the outline of the enceinte and of the ravelin, the same as those of the modern system, he raises a large mound at the salient of the latter by laying off 45 yards along each face, and raising it 44 feet above the plane of site or level of the country. This by its elevation entirely screens the faces of the ravelin from enfilade fire. Again the inner face and ditch of the redoubt of the re-entering place of arms, instead of terminating on the counterscarp of the ditch of the ravelin, is continued across the ditch to the counterscarp of the ditch of the redoubt of the ravelin, perpendicular to its face at the shoulder angle, cutting off therefore the face of the ravelin by making a coupure in it and preventing the besieger breaching the bastion down its ditch. The flanks of the redoubt of the ravelin are simply crenelled walls, in order not to give the besiegers any cover from which to drive the defenders from the redoubt of the covered way and the coupure of the ravelin, which are intended to be held till the last.

Soon after the commencement of the revolution, Bousmard, a French officer, who had entered the service of the king of Prussia, proposed to curve the faces of the bastions on the plan, in order to diminish or prevent the effect of the ricochet, and to build casemates in the flanks of the tenailles for the purpose of more effectually defending the main ditch. His traverses in the covered way are like little redans, each being a little retrenchment having a separate communication with the main ditch. But his principal improvement consisted in extending the covered way and glacis along the whole of the enceinte, and in placing the ravelin with its proper covered way and glacis on the exterior; in consequence of which disposition it would become impossible for the besiegers to breach the bastion by firing along the ditch of the ravelin, while the latter would possess all the advantages attending the greatest possible saliency. The ideas of Bousmard respecting the disposition of the ravelin were adopted by General Chasseloup de Labat, in the works which he executed, by order of Napoleon I., to strengthen the fortifications of Alessandria; and the same engineer constructed a strong polygonal redoubt of earth in each of the places of arms before the flanked angles of the bastions and ravelins, in order to increase the quantity of crossing and reverse fires in front of the works.

The last modification of the bastion system which it will be necessary to mention, is that proposed by Choumara, who, partly to diminish the pressure of the parapets on the escarp revetment, and to render the formation of a practicable breach more difficult, and partly to procure a close fire of musketry into the covered-way, suggests that a terreplein, like the old chemin des rondes, but with a slender breastwork to protect the defenders, should be left on the exterior of the parapets. The same engineer recommends that the flanks of the bastions should be lengthened by continuing them within the line of the curtain, and that they should have a greater relief than the latter, in order that a fire of artillery might be directed over it against the works of the enemy: he proposes also that a glacis of earth should be raised in the main ditch, high enough to mask the foot of the escarp revetment, and prevent it from being battered by a fire of artillery on the crest of the covered way.

As early as 1640, Dillichs, in a work published at Frankfurt, proposed a method of fortifying places, which consists in surrounding them by lines of rampart forming with each other a series of angles alternately salient and re-entering, being in fact a Tenaille system; and, subsequently to the time of Vauban, a few other projects of a like nature have been suggested. The most remarkable of these is that which was published in 1776 by the French General Montalembert, who entitles his method 'Fortification Perpendiculaire.' Its outline on the plan is a series of the sides of equilateral triangles formed on those of a dodecagon inclosing the place; the re-entering angles being consequently right angles, and, as the general has developed some useful ideas concerning the interior defence of a place, though no existing fortification affords an example of the method, a short description of it may with propriety be given.

Three parallel ramparts of earth, of the form above indicated, and separated from one another by wet ditches, surround the place: the berme at the foot of the first and third is protected by a simple wall, and that at the foot of the middle rampart is covered by a loop-holed gallery on its whole length. Beyond the outer ditch is the covered-way, whose re-entering angles are fortified by strong redoubts. In the re-entering angles of the two interior ramparts are formed casemated batteries, the fires from which would sweep the surface of the ditches in front, in the directions of their lengths; and, within the enceinte of the place, a circular redoubt, or tower, of brick-work, carrying several tiers of guns, is intended to defend the interior rampart, if, at length, it should be forced. The merit of this system is supposed to consist chiefly in the powerful fire which the casemates would afford, as from their situation, they would scarcely be injured by the enemy; in the difficulty which the latter would experience in getting over the detached walls; and in the great force which the defenders, by means of the spacious communications, might bring up to oppose the assailants.

During the existence of the first French empire, the celebrated Carnot proposed to restore the balance between the attack and defence of fortresses, which the inventions of Vauban had made to preponderate greatly in favour of the former, by means of powerful sorties from the place and an abundant discharge of stones and balls from mortars fired at considerable angles of elevation; thus annoying the besiegers in their trenches, and either putting great numbers of their men hors de combat, or compelling them to recur to the slow process of blinding their approaches. Adopting, in his method of fortifying places, the proportions of Cormontaingne for the plan of his bastions, but making the whole length of his front of fortification equal to 480 yards, he detached the bastions from the enceinte, which he made to consist of a simple polygonal rampart of earth. In rear of the tenaille between the bastions he placed a fausse-braye, whose exterior side was to be protected by a casemated tower at each extremity; and, behind the gorge of each bastion, he formed a row of casemate vaults, in which the mortars were to be placed for throwing stones, &c. into that work when gained by the enemy. Adopting also the ideas of Montalembert respecting detached walls, he proposed to surround the enceinte by one, which was to be loop-holed in order that a fire of musketry might be made from it, and to construct a similar wall before the faces and flanks of the bastions. The bastions were to be covered by narrow counterguards; a cavalier, or lofty redoubt, in front of the tenaille, was to defend the collateral faces of both bastions and counterguards; large ravelins were to cover the central parts of the fronts of fortification and afford crossing fires on the ground before the bastions; while mortars placed on the faces of the work and on the barbettes at the angles were to discharge their missiles over the parapets. A ditch surrounds the whole, and its exterior side is made with a gentle slope from the bottom to the level of the natural ground in front, for the purpose of facilitating the sorties; the corresponding facility which the enemy might have for descending into the ditch being disregarded on account of the supposed impossibility of maintaining himself there under the hail of stones and shot from the works.

It was supposed that the detached wall, being covered as before mentioned, would present an impassable obstacle to the assailants; but an experiment made at Woolwich in 1824, proved the possibility of breaching it by a fire of shot and shells, directed over the parapet of the counterguard, from artillery of great calibre, at the distance of 400 yards from the latter work. The efficiency of the vertical fire, as it is called, of stones and shot from the works has also been controverted; and experiments have been made which seem to prove that the momentum acquired by the missiles in their descent would not be sufficient to do serious injury to a man on whom they might fall, if he were protected by a proper head-piece.

We now come to what is variously termed the polygonal, right-lined, German or Prussian system. It has of late years been much adopted by German engineers, but has never yet been tested by an actual siege. Instead of the ramparts of the enceinte being broken up into bastions and curtains, they follow the lines of the polygon and are flanked by projecting masonry works called caponnières, something like Vauban's tower bastions, or Montalembert's casemated batteries, from which they are taken. The lines of defence may be about 300 yards, so that placing the caponnière in the centre of the side of the polygon this may be taken at 600 yards. The caponnière, projecting about 35 yards from the exterior, will contain 12 guns in 2 tiers of casemates on each side, that is twice as many as an enemy can place in a breaching battery against it; and if built with an interior court for ventilation would be about 30 yards in width. The caponnière is covered in front by a simple counterguard, or by a strong ravelin, and its sides flanked by gun casemates in the enceinte, the ravelin being flanked in the same way, or by casemates at its gorge. The detached escarp has commonly been employed in this system, of which perhaps the best example is Fort Alexander at Coblentz.

Besides these already mentioned, many ingenious systems have been advanced at various times, among which may be mentioned one by Lieut. Cook, late Professor of Fortification at Addiscombe College; Mr. Bordwine's system, and, still later, a further development of this latter by Mr. Fergusson. Mr. Fergusson's system has of late received so much notice from the able manner in which he has advocated it, that it would appear to require some description in this place; but in the limits of this article, though some idea might be given, it would be impossible to do it justice; the reader is therefore referred to 'Fergusson's System of Fortification.' It may be remarked, however, that ingenious as it undoubtedly is, and remarkable as are some of the ideas propounded, it has not attracted any large amount of support from engineers either in England or on the Continent; and though the author appears to attribute this principally to professional jealousy, &c., it must be acknowledged that it could hardly be carried out in its entirety, nor would it be likely to fulfil his anticipations. It is necessary to guard against the idea, in discussing the system, that the Russians employed it, and with such great success, at Sebastopol. This confused idea appears to have originated from the fact that Mr. Fergusson proposes a huge mound of earth divided into numerous parallel ramparts, and that the Russians used earth-works, though the former proposes to sprinkle his ramparts pretty freely with casemates, and the latter used unrevetted earthworks because they could make no other, and followed the ordinary plans which have been followed for centuries in field fortifications or entrenchments; never raising tier above tier of guns, except where occasionally one battery erected behind and on considerably higher ground fired partially over one in front. This may be easily seen by a very cursory inspection of the plans. The immense duration of the siege of Sebastopol is easily accounted for, when we remember that a large and powerful enemy, never numerically much inferior and occasionally superior to that of the allies, was defending in a naturally very strong position one of the largest and best supplied arsenals in the world, from which they obtained guns and ammunition in greater numbers, and of larger calibre, than the allies had, almost to the last, to bring against them; that their rear and communications were open, so that casualties could be replaced; that they had a powerful fleet in their well-fortified harbour, and a great number of the ships of which being sunk supplied them with artillerymen; that they had a large army of observation in the field constantly harassing the allies, and threatening, by such sorties as at Inkermann, to raise the siege; and, lastly, that even on the approach of the allies on the south side, they had sufficient permanent works, as the crenelled wall on the west, the central bastion, the Malakoff tower, &c., with their ships, to make a *coup de main* hazardous, if not impracticable, and thereby by obliging the allies to make batteries and bring up guns to destroy these, giving themselves time, which they certainly availed themselves of, to erect counter batteries and perfect their defences.

It is scarcely probable that any existing fortresses will be demolished for the sake of the advantages which would result from a re-construction according to any of the methods which have been proposed since the time of Vauban; but, on any future occasion which may present itself for fortifying a town or military post of importance, it may be found convenient to adopt some improvements in the construction of the works. Thus, the general system of Vauban, with the modifications proposed by Cormontaingne, being retained as the basis, casemates, like those of Montalembert, might be formed in the re-entering angles of the enceinte or tenailles, and detached walls or galleries for musketry in some of the dry ditches: detached ravelins, as proposed by Bousmard, may be constructed beyond those of the ordinary kind, in order to prevent the enceinte from being breached at the first crowning of the glacis; and a direct defence of the covered way may be obtained from galleries formed within, or on the exterior of, the parapets along the faces of the works.

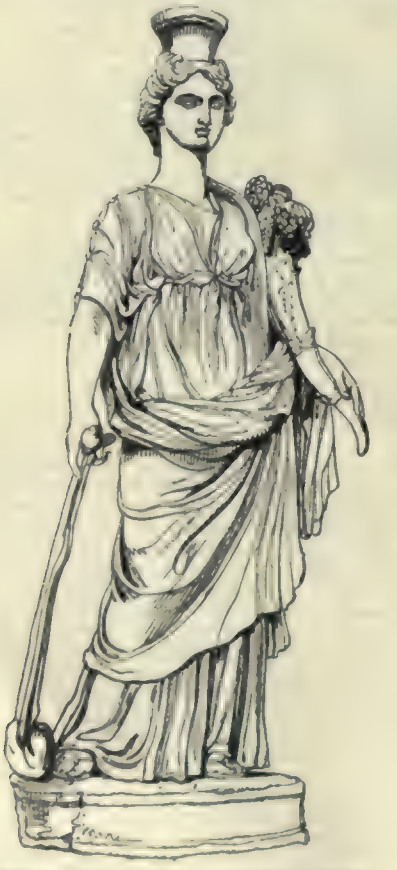
In the open attack of a fortified place it is evident that the loss of life would be so much the greater as the defensive works are stronger and better combined; and, in consequence, the necessity of making the approaches under cover to the last moment of the siege, would become more urgent.

For the works occasionally constructed beyond the glacis of a fortress, see FLÈCHE, HORN-WORK, LUNETTES, and TENAILLONS.

Of the works which fall under the denomination of field-fortifications, BRIDGE-HEADS have been already mentioned; REDANS, REDOUBTS, and STAR-FORTS are described under those words; and the combinations of works which serve for the protection of armies, that is, *Field Fortification*, under LINES OF ENTRENCHMENT. Small forts with bastions are frequently employed in field-fortifications: their plan is similar to that of the enceinte of a fortress; but they differ from the latter in their size, in having low relief, and in the sides of their ditches being unrevetted, or only faced with sods.

The limits of an article such as this, will only permit of the most cursory notice of this complicated and intricate subject: the reader is therefore referred for further particulars to the standard works, such as Bousmard's 'Essai Général de Fortification;' Dufour's 'Mémorial pour les travaux de guerre;' Carnot, 'De la Défence des places fortes;' Sir John Jones' 'Sieges in Spain;' Belma's 'Sieges in Spain;' St. Paul's 'Traité de Fortification;' 'Aide Mémoire (English) to the Military Sciences;' Capt. Macauley, R.E., on 'Field Fortification;' Lieut.-Col. Jebb, R.E., 'Treatises on Defending Outposts,' and 'The Attack;' Straith's 'Fortification,' revised and re-arranged by Cook and Hyde, 7th edition, &c.

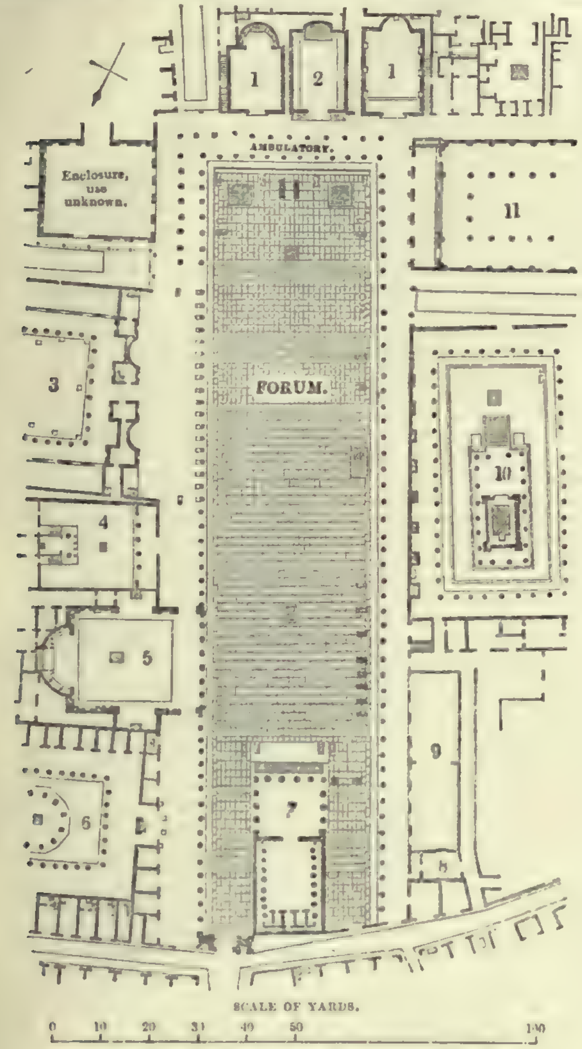
FORTUNE (Fortuna), in the Roman mythology, was a goddess who was supposed to dispose, at her caprice, of the destinies of men; corresponding in a great measure to TYCHE of the Greeks. This deity did not figure in the more ancient systems of theosophy; Homer does not mention Fortune in the Iliad, but refers the events of this world to the decrees of Jupiter and of Fate. Fortune however was worshipped in Italy of old; by the Etruscans at Volsinii, under the name of Nursia; by the Latins at Præneste; and by the Volsci at Antium, where a splendid temple was dedicated to her, in which a sort of oracles was delivered. She had several temples at Rome. As directing the events of life she was represented with a rudder; with a ball as typical of the instability of fortune; and with a cornucopia and occasionally with the modius as diffusing abundance and prosperity. We give an engraving of a statue of Fortuna, in which all these attributes are united: the original, a small but very graceful marble statue (3 feet 1 inch high) is in the Third Greco-Roman Saloon of the British Museum. (Lactantius, *Instit.* i. 29; Horace, *Od.* i. 35; Martial, *v.* ep. 1.)


Fortune. From the statue in the British Museum.

FORUM, a large open space in ancient Roman cities (corresponding to the Agora of the Greeks), usually surrounded with public buildings, where the citizens met to transact business, and where, previous to the erection of Basilicæ, causes were tried. From this last circumstance the word forum is used metaphorically for a place of justice. Nardini is of opinion, though without any show of authority, that the first forum, or Forum Romanum, at Rome, was placed on the Palatine Hill. The Greeks made their Agora square, with a double colonnade, or ambulatory, above and below; but in Italy the width of the forum was made less than the length by a third, and the columns set wide apart, as the gladiatorial shows were formerly given in the forum. (Vitruvius, lib. v. 1.) The Roman fora were of two kinds, Fora Civilia and Venalia: the former were for law and political affairs, the latter for the purposes of trade. Rome contained nineteen fora of importance,—the Forum Antonini, Archemorium, Argentarium, Augusti, Boarium, Cæsaris, Cupidinis, Nervæ, Olitorium, Piscarium, Piscatorium, Pistorium, Romanum, Sallustii, Suarium, Tauri, Trajani, Transitorium, and Vespasiani. Of these the Forum Romanum, Nervæ, Trajani, Boarium, and Piscatorium, alone retain any traces of the splendid edifices with which they were once adorned. The Forum Romanum is situated in a narrow valley, not far from the Tiber, between the Palatine and Capitoline Hills. It sweeps round towards the Fora of Cæsar and Augustus, which are between it and the larger Fora of Nerva and Trajan, all which, looking at their relative situations, were no doubt connected with it on the north. On the south it extended nearly to the Fora Boarium and Piscatorium, which were near the Pons Palatinus, now called Ponte Rotto: its exact limits are, however, uncertain. It was decorated with temples, statues, basilicæ, curiæ, rostra, triumphal columns, and arches, which usurped the place of shops, schools, and even private houses, that originally stood in this forum. In the forum were the rostra, or pulpits, decorated with the beaks of ships, whence the orators harangued. According to Appian, the rostra were placed in the middle of the forum; and he states that Sulla caused the head of young Marius to be hung up before the rostra in the middle of the forum. Varro, in his fourth book, 'De Lingua Latina,' places the rostra before the curia, which was near the Comitium, so that the orators would stand with their faces towards the capitol; but Plutarch, in speaking of the Gracchi, states the reverse to be the case.

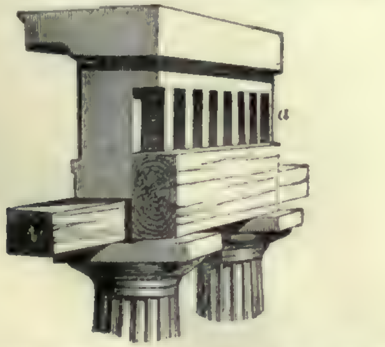
The Comitium was placed near the Curia; three columns of the former, commonly called the Temple of Jupiter Stator, still remain. Nardini places on the side of the Palatine Hill, in succession, the Fabian Arch, Græcostasis, Senalum, Basilica Opimia, Ædicula of Concord, Temple of Romulus, Temple of the Dii Penates, Curia Ostilia, near which was the Comitium, Basilica Portia, Temples of Julius Cæsar, and Castor and Pollux. On the side towards the Tiber stood the Temples of Jupiter Stator, Temple and Atrium of Vesta, Basilica Julia, house of Lucius Tarquinius, and the Temple of Victory. On the side of the Capitol were the Arch of Tiberius, the temples of Saturn, of Concord, and of Vespasian, the school of Xanthus, the Arch of Severus, which still remains, and the Tullian Prisons. On the north side of the forum were the office of the secretary to the senate, and the Basilica of Paulus Emilius. There are, however, but few remains existing of a small number of these numerous buildings, and the greater part have entirely disappeared. A single monumental column stands near the Comitium, called the Column of Phocas. Besides these buildings, there are remains of the temples of Fortune, Jupiter Tonans, Jupiter Capitolinus, and the Tabularium, though these are perhaps not within the boundaries of the forum. (See plates in Nardini's 'Rome,' vol. ii., lib. v., c. 1.) A very beautiful restored view of the Forum Romanum was made by Mr. C. R. Cockerell, R.A., and a reduced view was engraved and published, with his permission, in the second volume of the 'Pompeii,' published by the Society for the Diffusion of Useful Knowledge, to which we refer our readers for an accurate notion of the splendour of the accumulated architecture of the Forum and the Capitol, and its vicinity.

The forum at Pompeii was constructed in the Greek style, and has many Greek features. It is oblong, surrounded on three sides with rows of columns, forming, with the advanced columns of the various buildings, a colonnade or ambulatory; above this there was a second ambulatory, if we may judge from the remains of stairs at several places at the back of the colonnade. The fourth side of the forum is inclosed with two arches placed on each side of a large hypæthral temple, called the Temple of Jupiter. On the west side are the prisons and the granary with an enclosed court before it and the prisons; the Temple of Venus and the Basilica; and on the narrow side, opposite the Temple of Jupiter, are three buildings generally considered to be the Curiæ and Ærarium: on the east side is an enclosure, the use of which has not been determined, the Chalcidicum [CHALCIDICUM], the Temple of Mercury, the Senaculum, and a building supposed to be a large eating-house, generally known by the name of the Pantheon, in front of which are the Tabernæ Argentariæ. The enclosed area of the forum was paved with large square pieces of marble, and the sides of the area were adorned with statues. Opposite the curiæ and a short way from them is a small triumphal arch. The forum was closed at night with iron-barred gates, and it does not appear that chariots were admitted into it, as the pavement of the streets terminates at the back of the colonnade. The columns of the ambulatory are of the Greek Doric order, and were being restored in the same style, though with better materials, at the time the city was destroyed. The columns were aræostyle, and the architraves were most probably of wood, as we may infer from their being destroyed, while the frieze and cornice of stone remain.



Plan of the Forum at Pompeii.

1, 1, Curia; 2, Ærarium; 3, Chalcidicum; 4, Temple of Mercury; 5, Senaculum; 6, Pantheon; 7, Temple of Jupiter; 8, Prison; 9, Granary; 10, Temple of Venus; 11, Basilica.



Construction in wood and stone of the aræostyle portico of the Forum.

a, holes for the joists of the upper floor.

FOUGASS, a small military mine, formed by sinking in the ground, to a depth not exceeding 10 feet, a box of powder, or one containing two or more loaded shells. The train of powder by which it is to be fired is contained in a linen tube, and this is frequently protected by being placed in a case of wood. A trench is cut in the ground to receive the train, but it is subsequently filled up.

Fougasses are sometimes employed in the defence of field forts, and then they are formed under the glacis, or on the counterscarp, at the points where the assault is expected: in this case generally the train of powder is conveyed under ground to the counterscarp of the ditch, where the fire is to be applied; but occasionally this is done in the interior of the work, the train being then made to pass under the bottom of the ditch.

Sometimes a fougass is used to destroy a small work, in which case it is sunk within the mass of the rampart or parapet.

A stone fougass or rock mortar is formed by excavating a shaft in the ground at an inclination of about 45°, and about 6 feet deep. A charge of powder of 50 or 60 lbs. is placed at the bottom of this, with a shield of wood 6 inches thick placed on it. The charge of stones is then thrown in. There may be about 4 cubic yards of stone, each stone or pebble not being less than half a pound in weight; a sufficient body of earth being placed vertically over the stones to make them take effect in the right direction. The charge is fired as an ordinary fougass.

FOUNDATIONS. The surface which immediately supports a building is technically known under the name of its *foundation*, whether it be natural or artificial; and from this function arise the laws applicable to this particular branch of the arts of construction, namely, that, howsoever formed, the foundations of a building must not be susceptible of movement of any description whatever, after they shall have assumed the statical condition they were designed to assume when loaded to the fullest extent. It follows from the infinite varieties of the resistances of the apparent portions of the earth's crust under the various forces exercised by a building, that very great differences must prevail in the modes of dealing with foundations; and in addition to the difficulties attending this part of the science, other, and perhaps more serious ones arise from the circumstances under which the foundations themselves may have to be prepared or executed. They may, indeed, either be prepared in the open air, or under water, or without disturbing to any serious extent the natural compressible subsoil; and they may be either wholly or partially natural or artificial.

Natural foundations require little description here. They exist wherever the site upon which a building has to be erected is situated upon a homogeneous formation of sufficient thickness to render any lateral displacement of the bearing strata impossible. The only danger, indeed, of this class of foundations would arise from the tendency to such movement, and it therefore behoves the engineer or architect to inquire very carefully into the conditions of substratification, and of subterranean water-flow, which might be likely at any future time to develope changes in the statical conditions of the surface strata. Should there not exist any lower moveable beds, there are few rocks which may not be unreservedly trusted as foundations. Gravels, coarse sands, loams, and clays may equally be adopted, provided they be not unconformably deposited on the edges of a highly inclined basin of a rocky nature. Even soft alluvial deposits, when prevented from spreading laterally, may at times be resorted to as natural foundations; but both in this case, and in the one in which diluvial formations occur on the edge of highly inclined strata, care must be exercised in the manner in which they are used. In fact, any stratum which will support a vertical weight equal to 30 pounds upon the superficial inch without sensible compression, *after a month's trial*, may be considered fit to serve as the foundation of a building: provided always that there be no subjacent moveable strata. The lower courses or the footings of the building itself must therefore present a bearing surface proportionate to the resistance to compression likely to be met with in the natural foundations. Even when the latter are distinctly susceptible of vertical compression, there is, however, less danger from this cause than from their tendency to lateral displacement, especially when they are of a tolerably uniform character; and it is for this reason that it is essential to isolate the bearing surface of any important structure from any irregular or permeable strata whose particles might be displaced by any natural or artificial changes in the hydrographical conditions of the locality. As very few natural foundations are to be met with whose surfaces are sufficiently level to receive the footings of a building, it has been customary of late years to fill in their depressions (to regularise them, in short) by spreading a bed of concrete over them; and it may be received as a tolerably safe general rule, that every rock, gravel, or clay formation will resist a vertical crushing weight which may safely be brought upon the surface of the concrete itself. Of course the resistance of that material will depend upon the nature of the lime or cement of which it is composed; but as, under ordinary circumstances, the concretes made with the moderately hydraulic limes fulfil all the requisite conditions, its resistance may be taken as the limit of the safety load it is desirable to bring upon a natural foundation. Vicat estimates it at about 30 pounds per superficial inch, after the lime has had time to set fairly.

Foundations may be said to be *partially natural*, when the inequalities of level of the ground on which the building is about to be erected are so great as to require that they should be compensated for by the interposition of some extraneous substance; or when the resistance of the natural surface would not be sufficient to enable it to support the superincumbent weight. When the former of these conditions prevails, it is essential that precautions should be taken to obviate any danger which might arise from the movements of a different nature likely to occur in the natural and in the artificial portions of the foundations. When the latter condition occurs, the modes of dealing with the foundations so closely resemble the ones it is advisable to adopt with the more exclusively artificial class, that they are at once referred to it. Strata which are exposed to lateral displacement frequently require the execution of works of so complicated a nature, before a building can safely be erected upon them, that they can hardly be considered to belong to the category of the partially natural foundations, even when the natural surface of the ground is but slightly altered.

Artificial foundations are those which are required when the strata occurring at the surface of the ground, upon which it is proposed to erect a building, are of a highly compressible or of a moveable nature, and of such a thickness as to render it dangerous to bring a heavy load upon them, and impossible to remove the bulk of the soft material which thus covers the harder substratum. These conditions usually occur in situations wherein the surface stratum is composed of alluvial matter, or upon the shores of the sea, of lakes, rivers, or in morasses, peat deposits, &c., and the ordinary difficulties attending the execution of foundations in such positions are increased by the necessity for dealing with the water which accompanies those deposits. The nature of the works required to form artificial foundations will therefore depend mainly upon the question as to whether or not it be necessary to execute them in the open air; and when it is possible to avoid laying dry the surface to be operated upon, it becomes important to consider the effect of the water upon the durability of the materials which enter into the composition of the artificial foundations themselves.

In such cases as those which occur near the embouchures of the European rivers, where in fact a fine alluvial clay, sufficiently mingled with sand to allow water to permeate the mass, commonly overlies a more ancient and denser geological formation, it is customary to form artificial foundations by means of piles or baulks of timber, which are driven vertically, wherever it is possible so to do, through the alluvious into the harder substratum. Sometimes these piles act merely by the compression they produce upon the ground into which they are driven, but as a general rule they serve to support the superincumbent weight, somewhat in the manner in which pillars would do in the open air. In the former of these cases, the number of the piles is the most important consideration; and, as the resistance they have to overcome in driving is insignificant, their shape is a matter of indifference: nay, it may happen even that (as near l'Orient, where artificial foundations have been established upon soft mud of practically indefinite thickness) it would be desirable to drive the piles with their butt end downwards; —to trust, in fact, to the friction upon the sides of the pile for the limited degree of stability to be thus obtained. In the latter case, or when the piles have to transmit the weight to the resisting substratum, it is necessary to proportion the length and the transverse section of the piles to the load, and to cut the driving end in such a form as to ensure their entry into the bearing stratum. As they have to overcome considerable resistances in the course of their descent, they require to be shod either with cast or wrought iron, and to be hooped or bound with iron at the heads. The necessity for the latter precaution increases with the violence of the blows struck upon the head of the piles; and it has been even found that when the Nasmyth's hammer has been used, the frequent heavy blows at times either develope so rapid a compression of the fibres as to set the piles on fire, or they beat the heads into a spongy mass. The piles are also occasionally exposed to be split, if the shoe should encounter any very hard substance in its descent.

The description of wood used for piles ought to be a matter of serious consideration to the architect or engineer. Fir timber resists alternations of dryness and moisture better than either elm or beech (which are the other woods employed for this particular purpose); but if it should contain much sap at the time of its being driven, the fir will rapidly decay. Beech resists the constant action of water, but if it should be exposed to alternations of dryness it will rot; whilst elm timber presents an intermediate degree of durability under those circumstances. The boring worms constitute, it may be observed, one of the most fatal sources of danger to piles driven in the districts where these creatures abound, and they have naturally exercised the ingenuity of both theoretical and practical men to devise some protection against them. Sometimes the whole surface of the piles is, for this purpose, studded with copper nails; at others the wood is steeped in a variety of solutions, such as creasote, or corrosive sublimate; but unfortunately it does not seem to be possible to depend on the successful results of any of those operations. [PHOLADIDÆ, *Teredo*, in NAT. HIST. DIV.] It is said that the *green heart* is the wood which is the most free from the attacks of these destructive creatures, and that creasoting ordinary timber to some extent guarantees its immunity.

Piles are known by distinct names, according to the position they may occupy in a foundation. Thus, the piles which define the limits of the ground to be inclosed are known as the *guage piles*. When the space between the guage piles is filled in with other piles of the same scantling, the latter are called *close piles*; but if they should be of less thickness, they are called *sheet piles*. All these pieces of timber are tied together with horizontal *wales*, or by cross braces. Generally speaking, in foundations intended to support heavy structures upon very soft strata, an inclosure of either close or sheet piling is driven all round the intended situation; and then isolated piles, of about 12 or 14 inches square, are driven at distances of about 3 feet from centre to centre. Upon the projecting ends of these piles sleepers are laid, and close planking is fixed to them. At the present day, the heads of the piles and the sleepers are bedded in concrete, which is carefully rammed up to them, and levelled to receive the close planking. In many cases, also, in England, the planking is replaced by a layer of Yorkshire landings. In driving the piles, it is desirable to work from the outside, inwards; because in that manner the compression of the ground produced by the mere act of driving the piles tends to increase the solidity of the bearing surface. No notice is taken, however, of the additional strength thus obtained; but the load to be brought upon the piles is calculated as though they were intended to support the weight in the air without any lateral support. Evidently, under these circumstances, the safe load a pile may bear will depend upon the length of the pile itself. In practice, this consideration is frequently neglected, and constructors content themselves with the rough general rules, "that the diameter of a pile should be $\frac{1}{20}$th of its length, and that the safety-load of such a pile should be about 400 lbs. on the superficial inch of the sectional area." Under no circumstances, however, should piles of less than 7 or 8 inches in diameter be used.

The piles themselves are driven by several descriptions of engines, according to the resistance to be overcome, and also according to the magnitude of the work. If the piles have to be driven in soft uniform ground, such as that which is usually met with in the Fen districts of the eastern counties, or in Holland, the old-fashioned ringing engine will suffice; but if the ground should become gravelly, it may be necessary to use the heavy monkey worked by a crab, or the Nasmyth's hammer, or the pneumatic pressure upon the system of Dr. Potts's patent, or upon that of the adaptation of compressed air; although perhaps the two last-named methods of forming foundations are more particularly applicable to tubular foundations than to piled ones. The weight of the monkey used in ordinary ringing engines is about 12 cwt., and the fall attainable is about 4 feet or 4 feet 8 inches; in the case of pile-engines worked by machinery, the weight of the monkey varies from 16 to 22 cwt., and the fall ranges between 12 and 18 feet; in the Nasmyth's hammers, the monkey is made from 32 to 45 cwt., but the fall does not exceed 2 feet 6 inches. But whatever may be the machinery adopted for the pile-driving, that operation must be continued until the pile refuses to advance under a certain effort, dependent upon the nature of the effort itself. This is usually fixed, empirically, as follows: Assuming that the weight to be brought upon each pile is 25 tons, the pile is considered "to refuse" when a series of thirty blows from a ringing engine, with a monkey of 12 cwt. falling through a height of 4 feet, will not cause it to advance more than half an inch; or when a series of ten blows has been given by a monkey of the same weight worked by a crab, and falling through a height of 12 feet; or when a series of seventeen blows from a Nasmyth's hammer, weighing 34 cwt., and falling through 2 feet 6 inches, has been given, without producing a greater advance.

In the system of foundations known by the name of Dr. Potts's patent, the piles at times act in a manner which makes that word inapplicable to them; for they become, indeed, wells, or tubes, subsequently to be filled in with concrete. Thus Dr. Potts used occasionally small piles of wrought iron; but at other times, and as a matter of choice, he used large ones of about 6 or 7 feet in diameter; but both the large and the small piles bore upon a sharp continuous edge, instead of upon a point, as in the case of ordinary solid piles. The descent of the tubes was produced by the application of pneumatic pressure; there was fitted upon the head a cast-iron plate, the air was then withdrawn from the interior, and the pressure of the atmosphere upon the cap, forced the tube into the ground, until the air in the interior was compressed sufficiently to resist the pressure on the cap. The earth was then removed from the interior of the tube, and, when the latter had been sunk deep enough, the interior was filled in with concrete.

A curious method of founding bridges upon deep sands is used in India, to which attention may be called here. It consists in sinking brick linings in all respects like those used in wells, and these linings are sunk in precisely the same manner. The brick-work is built upon a wooden curb, and the ground in the interior and upon the curb is then removed, just as is done in well-sinking; and the interior is subsequently filled in with rubble or with concrete. It is said that the Indian divers carry on the operations of sinking these linings under great depths of water. A good description of the mode of executing the Indian well foundations will be found in the 'Excerpt Minutes of the Institution of Civil Engineers,' for May 12th, 1857, and in those for February, 1842.

The greatest improvement which has lately been introduced in the method of founding important structures, in situations wherein the natural surface of the ground was not adapted to receive them, is, perhaps, the system adopted in founding the bridges of Rochester, Saltash, of the Quarantaine at Lyons, Macon, Bordeaux, Kiel, and Szegedin. In these cases, large tubes were placed in the positions designed for the piers, and an air-tight lock, or chamber, was formed at the top, through which the workmen and the materials were passed. The earth within the tube was dredged out as far as possible by the ordinary processes; and, the various valves being closed, the water was forced through a syphon pipe by compressing the air in the interior. A pressure of one atmosphere (above that of the external air) was usually found to be sufficient for this purpose; but, in order to prevent any rising of the water, or any blowing of the sand, the air in the interior of the cylinders was compressed to about three atmospheres. The workmen then passed to the bottom of the seating, and removed into buckets, which were extracted through the air-locks, the earth which rose above the edge of the tube; and when subsequently the air in the interior was reduced to its normal pressure, the mere weight of the tube and the machinery upon it caused the tube itself to descend in a manner analogous to the descent of a well-curb. In the Rochester and Saltash bridges the tubes were sunk through the permeable, moveable strata until they reached the rocks able to constitute a natural foundation. In the Szegedin Bridge, however, the tubes were merely sunk so far as to obviate any danger of the undermining of the foundations by the action of the river, and a piled bottom was formed in them to receive the concrete. In some cases the tubes were formed of wrought, in others they were of cast iron.

One curious observation was made on the occasion of an accident to a tubular foundation of this description at Macon. A barge drove against a cast-iron tube, and broke it; and on attempting to repair the damage so done, it was found that, although the upper portions of the concrete filling (which had been executed with mortar made of the best hydraulic lime) had set, nevertheless the portions which had been immersed in deep water had not commenced to solidify. It would thence appear that there are some hitherto unexplained conditions, with respect to the solidification of mortar under great hydraulic pressure, to which the attention of engineers requires to be directed.

The various descriptions of artificial foundations mentioned above, are supposed to be continued to such a height above the water-line of the neighbourhood, as to allow the superstructure to be erected in the ordinary manner. In tidal rivers or in streams exposed to floods and sudden changes of level, it is however often desirable to carry the bottom courses of the substructure to such a depth below the normal water-line, as to obviate any danger from the removal of the sand, or earth beneath them. If the depth requisite for this purpose should not exceed 8 feet, a simple dam of impermeable earth will suffice to protect the works, and to allow the workmen to lay the masonry in the dry. But in such rivers as the Thames, where the tide rises from 14 to 18 feet, it becomes necessary to resort to the use of COFFER DAMS when it is required to carry the springing courses to any considerable depth below the low-water line. A description of these structures has already been given; as also has been given a description of the CAISSONS so much employed in the course of the last century; but it may here be added that the practice of engineers at the present day is decidedly to avoid the execution of either of these methods of forming artificial foundations, on account of the expense of the former, and of the uncertainty of the latter. The system now most generally adopted is to inclose the site of the intended structure with a close sheeting, to dredge out the interior very carefully, and to fill in the space thus formed with piles or concrete. Evidently the stability of a foundation of this description must depend upon the depth to which the protective sheeting is driven; it must be carried below the extreme range of the scouring power of the river.

Of late years cast iron has been very successfully substituted for wood in the piles and plates, or sheeting, intended to inclose an artificial foundation. Examples of this description of structure are to be seen at the Blackwall Railway Quay, the Victoria Docks, &c.

When buildings are to be erected upon soft compressible peat, and the hydrographical conditions of the district are not likely to be changed, it may suffice to inclose the whole area of the foundations with a piled or plated sheeting, and to replace a portion of the peat by a layer of sharp silicious sand. In fact sand to a great extent acts like an incompressible fluid under a heavy load, and the effort exerted upon one portion of the surface is distributed over the whole, provided the sand be prevented from spreading. Care must, however, be taken that the subjacent peat should not be subject to lateral displacement, and that whatever compression may take place should forcedly take place in a vertical direction. The seatings of some of the German railways, carried over the immense peat bogs of that country, are occasionally thus formed upon pillars of sand, formed by filling large square holes sunk through the body of the peat itself; and in some other instances holes were bored through the peat, and subsequently filled in with sand.

A method of forming artificial foundations was formerly much resorted to in the neighbourhood of London, and in other analogous positions, in which the superstructure was carried upon timber platforms so designed and put together as to distribute the weight over a very large area. The success of this system depends, firstly, upon the strength of the platform, which must be sufficient to resist the partial actions of the load; and secondly, upon the durability of the platforms themselves. If any change in the conditions of the moisture of the ground should take place, by improved drainage, or otherwise, the timber may rot, and of course the building erected upon it will be dangerously affected. This danger, it may be added, is far from an imaginary or theoretical one; for in the southern districts of London the changes made of late years in the sewerage have so modified the ordinary state of the surface strata, that the old timber platform foundations are generally decaying.

Whatever may be the description of artificial foundations used, or whatever may be the character of the natural foundations resorted to, it is essential that the weight of the superincumbent structure should be distributed in the most regular possible manner, over the whole bearing surface of the foundations. It is for this purpose that the best builders make a practice of carrying the lower courses of their structures, evenly, under all the walls, and of executing them with the largest and most homogeneous materials they can obtain. The footings, as these lower courses are specially called, are made wider than the upper work, and even when large openings have to be made in the elevation, the weight thus thrown upon the piers, by the sides of these openings, is distributed over the whole area of the footings by means of inverted arches. In countries where brickwork is principally used, and where cement is accessible, it is often customary to introduce, immediately above the footings, a deep band of brickwork in cement, which serves not only to tie together the mass of the wall, but also to intercept the capillary action of the materials of the upper wall upon the moisture in the ground. Where, however, this system cannot be carried into effect, it is essential that precautions should be taken to ensure the strength of the masonry in this part of the structure, and to distribute the effort exercised upon any one portion of it over the widest possible area by the use of the largest blocks in the footing courses. These courses, it may be added, should be made to project on either side of the vertical walls, and to present a number of sets-off proportionate to the weight and character of the superstructure. The width or projection of each set-off should in no case exceed the height of the course itself; but perhaps the most important general remark to be made upon this branch of construction is after all that the materials used in the footing courses should be of the hardest and most impermeable descriptions, and those which would be the least likely to decay under the action of alternations of dryness and humidity. The durability of a building in fact depends so much on the measures which may be taken to prevent the absorption of moisture by the foundations, that it is impossible to exaggerate the precautions to be observed in the selection of their materials. [LIMES; MATERIALS FOR BUILDING.]

FOUNDING; FOUNDRY. Founding or casting is one of the mechanical arts which embraces all the operations of reducing ores, and of smelting and casting metals. There are various branches of the art; and some difference prevails in the minor details of the processes —as in iron-founding, brass- and bronze-founding, cannon-founding, type-founding, and bell-founding. The finishing operations of chasing, burnishing, plating, &c., are also parts of the founder's art. Under the names of the chief metals, as well as in such articles as BELL, CANNON, TYPE, &c., various processes of founding are described; in the present article we shall treat of the general features of the art, especially in connection with large iron castings.

It is certain that the art of founding is of very high antiquity. From the passages in the Old Testament referred to under BRONZE, we find that Tubal Cain was skilled in working in metals, and that the arts of metallurgy were known and practised very extensively by the early Israelites. The extent to which metal-working was carried on by the ancient Egyptians, Assyrians, Phœnicians, Greeks, Etruscans, and Romans, and the excellence to which it was occasionally carried in the fine arts, are too well known to need further observation in this place: a general history of it, as a branch of sculpture, has already been given in the article BRONZE, which also contains some notices from the ancient writers on the different methods adopted of solid hammer-working, hammer-work in plates, and casting; as well as on the varieties and composition of metals. In all the practical points of ancient founding our information is however very limited; the writers of antiquity having confined themselves, generally, to a description of finished productions, and leaving us little or nothing by which we can judge of the mode of working.

It appears that furnaces of considerable size, and producing a great tonnage of metal, were constructed in this country as early as the reign of Elizabeth; but it was not till the beginning of the 17th century that there was effected any great change in the character and importance of founding. Prior to that date all the operations of melting, &c., had been performed by means of wood fuel; but the demand for various objects in metal was now so greatly increased that it was evident, first from the consumption of timber for the foundries, and next from the destruction of forests in consequence of the agricultural improvements which were taking place in various parts of the country, that this provision must soon prove insufficient to meet the wants of the trade. It was then that the attempt was made to bring coal into use; and it is curious at this time to know how much difficulty, first from ignorance of its real value in the operations of metallurgy, and then from prejudice against such an innovation upon the old habit of burning wood only (to which must also be added the interference with the interests of wood monopolists), was thrown in the way of its introduction. One of the earliest and most zealous advocates for its use, Dudley, had all his works destroyed, and was nearly ruined by the violence of his opponents; but at length the employment of coal was fully established; and from that time the rapid advance of the iron and other metal works of this country may be dated.

We have stated the chief reason for having recourse to the coal-mines for fuel to have been the apprehension that the supply of wood fuel would fail. It is important to bear in mind, however, that, but for this well-grounded fear, wood or charcoal would always have been preferred for many of the operations of metallurgy; from its being less objectionable, as regards its chemical composition, than coal. The iron that is smelted in Sweden by wood fuel is considered a superior article, and is much sought after; and the smelters in this country find it necessary to char or coke the pit and sea-coal which they use, in order to adapt it to the purposes required. [Coke.] We shall now glance rapidly at some of the operations in the reduction of the ores of the four metals which are produced and worked in the greatest abundance in this country—iron, tin, copper, and lead: referring the reader to the articles under the names of those metals for further details.

Iron is obtained from a very abundant ore in this country, namely, the common ironstone of our coal-measures. For the reduction of the ore to a metallic state it is necessary to add a certain quantity of lime, which acts as a flux; and it is worthy of remark that, while the ore itself from which the metal is produced, and the coal for smelting it, are found together, the limestone by which its reduction is facilitated usually abounds in the lower regions of the carboniferous strata. Sometimes, as in the great coal basin of South Wales, a bed of millstone grit capable of enduring the fire, and used in constructing the furnaces, is also found in connection or alternating with the iron ore and limestone. The first operation the ore undergoes is *roasting*. This is done in various ways, both in this and in other countries. Sometimes it is conducted in kilns, sometimes on the ground in the open air. The first method is by heaping the iron ore on a mass of ignited coal. In the other, a thick layer of ironstone, broken in pieces, is placed upon a bed of coal, wood, or charcoal (on the continent wood or charcoal is always used), 6 or 8 inches thick, and covering an area of several yards; upon this another layer of fuel is placed, and then another pile of ore, which diminishes both in area and thickness towards the top. The whole is then covered with small coal or charcoal dust till it reaches some feet above the ground. The lower stratum of fuel is then lighted, and by degrees ignites the whole mass. In the course of a few days the ironstone becomes cool, and the sulphur, arsenic, water, and inflammable matter being driven off, it is fit for smelting. It is then placed in a furnace, with fuel and limestone in determined proportions. At Dudley, in Staffordshire, for 2¼ tons of roasted ore, which affords a ton of cast metal, 19 cwt. of transition limestone are employed as flux. In the course of a few hours the whole runs down, and the iron is melted, and in that state is allowed to flow into furrows made in sand, where it forms what is termed *pig-iron*; or it is poured into moulds where it forms the various articles of cast-iron ware. There are various sorts of cast-iron, but it is usually divided into three classes relatively to its colour and qualities, which are in this country called *numbers one, two, three*; sometimes more descriptive names are given to the different qualities, as *smooth-faced*, *gray*, *white*, *forge pigs*, *ballast*-iron, &c., &c. Cast-iron is converted into *bar*-iron by smelting it by means of charcoal, when it is welded and hammered; of this there are also varieties, of which the toughest, called *stub*-iron, is used in forming fowling-piece barrels. It is made by inclosing old horse-shoe nails tightly in a broad iron ring, generally made of Swedish iron; a welding heat is then applied, and the whole mass is hammered till by degrees the nails and ring become completely united: it is then drawn into bars, which make an iron of peculiar closeness, toughness, and malleability. These matters are further treated under Iron Manufacture.

The best ore of tin is found in Cornwall. It is commonly blasted by gunpowder, and is procured in pieces of considerable size, which are stamped to powder by beams shod with iron: it is then well washed till the earthy particles are carried off, and the tin is fit for the smelting house. After being roasted in a reverberatory furnace, and again washed, it is a second time subjected to the furnace, being now mixed with small coal, and in some cases, with a small quantity of lime. The melted tin thus produced is at last placed in a small furnace and exposed to a very gentle heat, when the purest portion melts first and is drawn off. This is called *common grain tin*; and the inferior, which still contains a small proportion of copper and arsenic, is then cast into pigs called *block tin*. The finest grain tin is procured from the stream works of Cornwall. Good stream tin affords from 65 to 75 per cent. of the best *grain*. For the details of operation, see Tin.

The reduction of copper ore is made by several consecutive processes. The first is by calcining it, and when the ore is sufficiently *roasted* to oxidate the iron which it contains, it is melted. The melted metal is after a time suffered to flow into a pit filled with water, by which it becomes granulated. It then undergoes further heating, and what is called technically its *slag* (or scoria) is taken off, and it is again allowed to run off into water. After other nearly similar processes the copper is cast in sand, when it becomes solid, and in this state is called *blistered copper*. It is now fit for what is termed the refinery, and undergoes an operation called refining or toughening. This is an operation of delicacy, requiring great skill and care in the workmen. The refining is conducted in a furnace similar to the melting furnace; the object is to thoroughly purify the metal from any portions of oxygen, which is performed by adding charcoal to the copper while it is in fusion, and stirring it occasionally till it is judged to be pure. The chemical relations of this process are noticed under Copper. When tin is united with copper, it forms the compound called *bronze*. [Bronze.]

The greater part of the lead met with in England is procured from a substance called *galena*, in which it is found combined with sulphur. There are, however, other ores of lead. The galena, being freed by hammering it and by the hand from whatever impurities can be separated from it by those means, is broken up into small pieces, and after repeated washings is placed in a reverberatory furnace; but only sufficiently heated to drive off certain ingredients without melting the lead itself. The *roasting* being finished, charcoal is added till the reduction is completed. The lead, after the *slag* has been removed from it, is suffered to run out of the furnace into a pan, and being first skimmed is ladled out into moulds and left to cool. There are various methods adopted in different places and under different circumstances for procuring the metal from the ores: these will be found succinctly noticed under Lead.

The furnaces that are used in founding are chiefly of two kinds, and though strictly speaking both are *air* furnaces, yet they are distinguished as *air* or *wind* furnaces and *blast* furnaces. The first acts by a draught through a chimney; whereas in the other the air is forced into the body of the furnace by means of bellows. The forms and relative proportions of the different parts of the furnace, and particularly the size, elevation, and direction of the chimnies, and the dimensions and space of the flues when these are required, are of great importance; the volume and intensity of heat and consequent certainty of the operations depending in a great measure on the knowledge and science displayed in adapting the parts to each other. The chief points of difference between wind, blast, and reverberatory furnaces are described under Furnace.

Founding is practised either by melting or casting any quantity of metal in the solid, or with a core (by means of which the metal is preserved of a determined thickness or substance), or in plain casting. Before any object can be cast in metal it is necessary that a model of it be prepared. The models may be made of various substances; clay or wax, or sand with clay, are those usually employed, but they may also be of wood, stone, or any other material. Upon those models *moulds* must be made; these are commonly composed of plaster of Paris mixed with brickdust, sometimes sand, or sand with a mixture of cow-hair. For moulds for iron and brass work a yellowish sharp sand is preferred, which is prepared by mixing it with water and then rolling it on a flat board till it is well kneaded and fit for use. This process is called, in technical language, *tewing*. If the model is cylindrical, or of a form that admits of such a process, it is moulded or cast in two pieces; these two parts are then carefully joined together, and the edges or seams trimmed. This doubling is an easy and cheap mode of execution, and only requires care to be successful. For the smaller class of works, instead of melting and running the metal at once from a large furnace, earthen crucibles are used, into which the metal is thrown in small pieces: the crucible is placed in a strong heat in a close stove, and as the metal is melted and sinks more is added till the vessel is full. It is then lifted out by means of iron instruments adapted to the purpose, and the metal is poured from it into the moulds, in which channels or ducts for receiving it have been previously made. There is one great advantage in using crucibles; namely, that the metal may be carried in them to any part of the foundry, whereas in general it is essential to have the moulds and the furnace close together. It is obvious however that melting metal in crucibles can only be practised where the casting is on a comparatively small scale.

In noticing the different ways of casting, mention has been made of one in which a core is used, and which may require some explanation. The *core*, as its name denotes, is a part or portion situated within the body of the cast; and its purpose in founding is to form a centre to the work by which the thickness or substance of the metal may be regulated. In coring, the mould must first be made complete; into this, clay or wax, or any other fit substance or material, is then squeezed or pressed in a layer of uniform thickness; in large works it is usually from half an inch to an inch thick. This layer represents the metal. The mould, if in parts, is then to be put together, the above-mentioned layer being left within it; and into the open space in the centre a composition (usually of plaster of Paris with other substances mixed with it) is introduced, and made to adhere to, or rather is filled up to the clay or wax. This is the core, and it is often made to occupy the whole interior of the mould. When this is *set*, or dry, the mould is taken to pieces and the material which has been made to represent the metal removed. The mould is then again put carefully together round its core or nucleus, the two portions being secured from contact by stops and keys properly arranged for that purpose. It is now obvious that when the mould is placed, with its channels and ducts, to receive the metal, this latter can only enter the interstice or space between the outer *mould* and the inner *core;* and thus, by an ingenious and simple contrivance, the cast is insured of sufficient substance to answer every object required, with, at the same time, a great saving of metal and reduction of weight.

In all these operations it is essential that the mould and the cores be perfectly free from moisture; seeing that the sudden and violent expansion of air that is at all damp, upon the heated metal flowing into the mould, would cause it to burst, to the destruction of the work and the great danger of the workmen. In order to guard against this, the moulds and core are usually placed in an iron closet or drying-stove, in which large fires are constantly kept up, and from whence they are not removed till it is ascertained that they are perfectly dry, and just before they are required for the casting. The moulds and cores of works of large dimensions are usually strengthened with bars and hoops of iron, to prevent them from springing or changing their form during the drying, and during the necessary moving and shifting about in the foundry. All that is now necessary before casting is to cut the channels or ducts for the metal to penetrate easily and quickly into the mould; and to place the mould conveniently with respect to distance and inclination from the furnace. The first operation is easily performed; the founder takes care to distribute the channels, both in number and in their size (or width), according to the parts of his work into which he requires a greater or less volume of metal to flow, and also, if the object be of great extent or complicated form, that the different parts of the mould may as nearly as possible be filled simultaneously; it being most desirable that the whole *getto*, or cast, should be made before the metal in any of the parts has time to settle or lose its fluidity. Other channels are also made for allowing the air to escape as the melted metal enters the mould; these are called vents, and are very necessary where the works are on a considerable scale. With respect to placing the mould, it is only important to secure a sufficient inclination of plane from the mouth of the furnace to the mould that the metal may run easily and uninterruptedly, and not have time to grow cool and therefore sluggish. The usual method in great bronze works is to bury the mould in a pit a little below the level of the furnace, and by ramming sand firmly round it to insure its not being affected by any sudden or violent shock, or by the weight of metal running into it. When everything is ready, and the metal found to be in a state fit for running, the orifice or mouth of the furnace (which is usually plugged with clay and sand) is opened, when the metal descends, and in a few minutes the mould is filled. The metal is allowed to run till it overflows the mouths of the channels into the mould. The work is then left to cool, after which the mould is scraped or knocked off and the cast undergoes the necessary processes (such as cleaning, chasing, &c.) to render it fit for the purpose designed. The variations which the processes undergo, in treating different metals and manufacturing different articles, will be found noticed under Bell, Brass, Bronze, Cannon, Iron Manufacture, &c.

Among the most remarkable modern specimens of founding, for their vastness of size and weight, are the cylinders and cranks of the *Great Eastern* ship; the iron tables for some of the plate-glass manufactories; the bed-plates for the larger kinds of machinery; some of the mortars on which such large sums of money have lately been unprofitably expended; and the two unfortunate bells for the Westminster palace. As was said under Bronze, the largest castings for fine arts purposes are frequently not made in a single piece; thus, the largest bronze statue of modern times, the colossal figure of 'Bavaria,' 61½ feet in height, placed in front of the Rühmeshalle, near Munich (modelled by Schwanthaler and cast by Fras. Miller at the royal foundry), was made in many pieces; and the largest of those did not nearly equal in weight the masses of iron above adverted to.

We may briefly notice here a method introduced in 1859 by Mr. Jobson, for casting shells and other articles. The pattern is made with arms carrying pins or projections, entering sockets in the plate on which the casting-box is placed. When the pattern has been correctly adjusted upon the plate, the pins and the ends of the sockets are filed, so as to make the ends of the pins and those of the sockets coincide; this affords a test for the workman to judge of the accurate adjustment for each casting. To facilitate the introduction and removal of the moulding sand, apparatus is arranged whereby the sand is shovelled upon sieves, which are worked mechanically; the sand is damped and sifted, and is carried by a sort of Archimedean screw to the mixer, where fresh sand and other matters are added, and whence the sand is conveyed through another trough by a screw into a position to be used by the moulder. In instances where heavy casting-boxes are employed, a peculiar form of crane is used; it consists of a quadrant, a chain or band passing over the quadrant, and a train of rack-and-pinion work; by this agency the box is raised, lowered, and moved laterally, with much facility.

For the various processes to which metal is subjected after founding, see Chasing; Embossing; Lacquering; Soldering, &c.

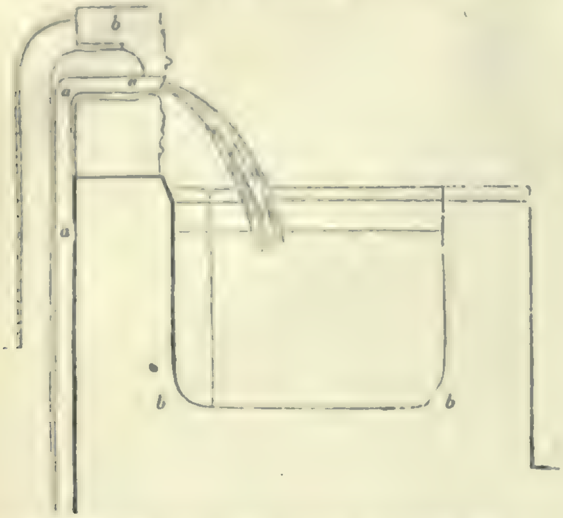
FOUNDLING HOSPITALS are charitable institutions, which exist in most large towns of Europe, for taking care of infants forsaken by their parents, such being generally the offspring of illegitimate connections. These institutions date from the Middle Ages, and were established for the purpose of preventing the destruction of children either by actual violence or by being exposed in the streets or highways. Among the Romans and other nations of antiquity, the exposure of children by poor or unfeeling parents was a frequent practice, and was not punished by the laws. After Christianity became the religion of the empire, it was forbidden by the Emperors Valentinian and Gratian. At the same time, the greater strictness of the laws concerning marriage and against concubinage, the religious and moral denunciations against unwedded intercourse, and afterwards the obligatory celibacy introduced among the clergy, and the severe penalties attending its infraction, all tended to increase the danger to which illegitimate infants were exposed from the sentiments of fear and shame in their parents. Child-murder and the exposure of children became nearly as frequent in Christian countries as they had been in Heathen times, only the parents took greater care to conceal themselves; and humane individuals in various countries began to devise means to collect and provide for the forsaken infants found in the streets. In this, as in other acts of charity, ecclesiastics stood foremost. At Rome, Innocent III., in 1198, when rebuilding and enlarging the great hospital of S. Spirito, allotted a part of it to the reception of foundlings, several infants having been found drowned in the Tiber about that time. This asylum for the "esposti," or foundlings, was afterwards enlarged and endowed by subsequent popes, and the institution was adopted by degrees in other cities. It was thought that by providing a place where mothers might deposit their illegitimate children in safety without being subject to any inquiry or exposure, the frequent recurrence of the crime of child-murder would be prevented. For this purpose a turning box was fixed in an opening of the wall in a retired part of the building, in which the child being deposited by the mother in the night and a bell being rung at the same time, the watch inside turned the box and took the infant, which from that moment was placed under the protection of the institution, was nursed and educated, and afterwards apprenticed to some trade or profession. Those parents who were in hopes of being able to acknowledge their child at some future time, placed a mark or note with it, by which it was afterwards known when they came to claim it, and it was then restored to them on their defraying the expense incurred for its maintenance.

In France, the philanthropist Vincent de Paul, the founder of the Society of the Missions in the first half of the 17th century, exerted himself to found an asylum for infants, which were at that time frequently left to perish in the streets of Paris. It was at first supported by private subscriptions, but afterwards was made a national establishment—"Hôpital des Enfans trouvés." Similar institutions were founded in other great French cities. Mortality appears to be very great in most foundling hospitals of the continent, owing to carelessness, mismanagement, or want of sufficient funds for the administration of those institutions. The infants are given out to cheap nurses in the country where a great number of them die. At the same time, it is remarkable that the number of illegitimate births has greatly increased over all Europe.

The principal objection that has been raised against foundling hospitals is, that they tend to increase the number of illegitimate offspring. In London, the institution of the Foundling Hospital, though it seemed to have prevented the exposure or murder of infants for a time, was found to produce such ill effects, that the object of the foundation was materially changed, and it is now a receptacle for illegitimate children on the application of the mother, who must prove the abandonment of it by the father, and whose character otherwise must be a good one. One distinction ought to be made, namely, that in countries where there is no legal provision for the poor, foundling hospitals appear to be more necessary, or at least less objectionable than in those where the mothers of illegitimate children, if unable to support them, have, like other destitute persons, the resource of the parish poor-house. It must also be observed that mothers of illegitimate children often neglect their unfortunate offspring, and are ill calculated by their habits to rear them up so as to make of them useful and honest members of society.

FOUNTAIN, a jet or jets of water, flowing either naturally out of the earth, or from structures formed by art. Artificial fountains consist of water flowing from vases, statues, sculptured ornaments, or architectural buildings combined with sculptured figures and other ornamental decorations.

Many ancient Greek cities were decorated with fountains. Pausanias informs us that Corinth was adorned with several fountains; and he mentions one in particular which stood near the statue of Diana, representing Pegasus, with the water flowing through his feet (ii. 3, 5). He describes another as consisting of a bronze Neptune seated on a dolphin, from the mouth of which the water issued (ii. 2, 8). Frontinus, who lived in the reigns of Nerva and Trajan, was superintendent of the fountains at Rome, and wrote a work, 'De Aquæductibus Urbis Romæ Commentarius,' in which he treats, among other things, of the distribution of the waters of fountains. The public fountains of Pompeii, some of which are almost perfect, evince the knowledge which the ancients possessed of the property of water to rise to its level, and their practical application of the principle.



Section of Fountain, from Pompeii, showing the ascending pipe, *a*, *a*, *a*.

Not only were the streets, but even the private houses of the Pompeians, decorated with fountains; and it appears that the ancients were acquainted with that law by which fluids may be made to ascend in a vertical jet to a height proportionate to the pressure which acts upon them.

Fountain, from the paintings of Pompeii.

One of the domestic fountains of the Pompeians is encrusted with coloured glass and shells. The fountain of water flowed from a large mask set on steps, placed within a large niche.

At Rome, the proper distribution of the rivers which flowed through her aqueducts was a matter of great importance, entrusted to the care of an officer of very high rank. It appears from Frontinus, who filled that office under the emperor Nerva, that the letting out of the public waters to private persons was a source of revenue. The right to a supply of water was strictly personal, not attached to houses, so that the supply was cut off at every change of ownership. The waters which had once been granted were sold by the superintendents, as they fell in, to the highest bidders. Those whose means or interest were insufficient to obtain a private pipe, were obliged to fetch water from the public fountains. ('Pompeii,' vol. ii. pp. 73, 74.)

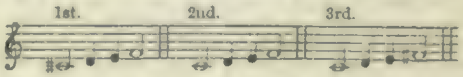
The number of leaden pipes found in Pompeii leads us to conclude that they were universally employed in fitting up the fountains of that city. Some fountains flowed through bronze figures, of which several are preserved in the museum at Naples. Specimens of the domestic fountains of the Romans (of marble) may be seen in the Græco-Roman Basement Room of the British Museum.

Some of the cities of Italy and the East are adorned with fountains, which are no less agreeable to the eye than useful to the inhabitants. Of all places, modern Rome is perhaps most abundantly furnished with this agreeable convenience, though this profusion is probably only a tithe of the luxury with which the ancient city was supplied. Many of the fountains of Rome are highly decorated, of great magnitude, and very varied in their mode of ejecting the waters with which they are supplied from the existing aqueducts. The fountains of Trevi, and the Pauline fountain at San Pietro in Montorio, are immense piles of architecture, the former highly decorated with sculpture. In Italy, almost every species of design which the imagination can form has been adopted by their ingenious artists in the construction of fountains. Many of those produced during the Medicean period are works of great artistic power. The fountains of the Saracenic architects, as shown in Spain, Cairo, and Constantinople, exhibited in their best day great fancy, lightness, and brilliancy of design, and a style singularly appropriate to the purpose and to the character of the surrounding buildings.

The city of Paris is well supplied with fountains, many of which are elegantly designed. The fountains of Versailles and St. Cloud in France, and the fountains at Wilhelmshohe near Cassel, were the largest in Europe prior to the construction of those at the Crystal Palace, Sydenham. Now the entire "system of fountains," as it is called, at this latter place may take rank, both as regards extent and brilliancy of effect, with anything previously produced.

London, though well supplied with water, has few fountains which make much pretension as works of art. During the past year, many small mural fountains, and a few standard fountains have however been erected in London and its vicinity, chiefly through the exertions of a society called the Metropolitan Free Drinking-Fountains Association. The primary object of this society is to erect as large a number of free drinking-fountains as possible, and with little loss of time. Eventually it is hoped that 400 such fountains may be erected in and around the metropolis. Utility rather than beauty, and economy of cost, are consequently leading principles in the preparation of the fountains of the association. In order, however, to combine a measure of ornament with utility, several designs have been selected, each of which serves as a pattern for a number of fountains; but few if any of the designs yet produced exhibit originality or fancy, and from the mode of reproduction the fountains show little individuality of character. Drinking fountains, similar in principle to these, were first introduced at Liverpool a few years back by Mr. Melly, a merchant in that city, who at his own cost erected several in the busiest localities. The example is being followed throughout the country, and already several hundred drinking-fountains have been erected. The majority of these are comparatively humble structures, but perhaps some of the most successful in an artistic point of view have been erected in provincial towns.

FOURTH, an interval in music, and to be enumerated among the discords; though it seems to have puzzled many writers on music, some of whom are much inclined to view it as a concord. [CONCORD.] Its ratio is 4 : 3. Of fourths there are three kinds: the *Diminished Fourth*, the *Perfect Fourth*, and the *Extreme Sharp*, or *Superfluous Fourth* (called also the *Tritonus*, from being composed of three whole tones). The first (C♯, F) is composed of a whole tone and two semitones; the second (C, F) of two whole notes and a semitone; and the third (C, F♯) of three whole tones. Example:—



FOWLING, the act or art of taking birds with nets, by shooting, snares, the use of bird-lime, or other devices. It is also sometimes used for the taking of birds with hawks and falcons, more properly called falconry. In Latin this sport is termed Aucupium. See Bargæus 'de Aucupio,' liber i., 'ad Franciscum Medicem Florent. et Senens. Principem,' 4to. Flor. 1566. Olina's 'Uccelliera,' 4to. Rom. 1684, is another work on fowling, the plates of which, representing the different modes of following the sport, are extremely curious. In English we have Blore's 'Gentleman's Recreation,' fol. Lond. 1686 and 1716; and 'The Experienced Fowler, or the Gentleman's Recreation,' 16mo. Lond. 1704.

FRACTIONS, COMMON AND DECIMAL. By a fraction is meant, in the first instance, a part of any magnitude. Thus, "three and a fraction" means three units and a part of a fourth. The next meaning of the term confines fractions, in an arithmetical point of view, to the *aliquot* parts or *submultiples* of the unit; which unit must therefore be divided into a number of equal parts, of which parts a certain number is to be taken.

Under the heads ADDITION, &c., will be found the various rules by which operations containing fractions are conducted. We shall here confine ourselves to fundamental points connected with the theory.

A fraction is thus denoted: $\frac{a}{b}$ means the quantity obtained by dividing a unit into b equal parts and taking a of those parts. If a be greater than b, it will obviously be necessary to divide more units than one, each into b equal parts, until enough have been subdivided to furnish the a parts required. It was usual, in English works on arithmetic, to call fractions in which a is less than b, *proper* fractions; and all others *improper fractions*; this absurd distinction is now beginning to be abolished. In the preceding fraction a is called the *numerator*, and b the *denominator*. The first term is correct, for a is the number of parts of a certain kind which are to be taken; the second is not quite so correct, for the denomination of which the number a is to be taken, is not b, but $\frac{1}{b}$; the bth part of a unit (not b units) is to be repeated a times.

On the whole, the terms *numerator* and *denominator* are very appropriate; but they are very long. Should they ever come into vulgar use, they will be shortened into *numer* and *denomer*; and it would be well if arithmeticians would do this for themselves.

The preceding fraction may be considered in several different ways. It is 1st, the bth part of a unit repeated a times; or, in common language, a-$b$ths of a unit; 2nd, the number of times, or parts of a time, or both, which a contains b; 3rd, the proportion which a is of b; 4th, the expression which ought to be written for a, on the supposition of that which was b units being made the unit. Thus $\frac{2}{5}$ expresses two-fifths of a unit, the part of a time which 2 contains 5, the proportion which 2 is of 5, and the expression which must be written for what is now 2, when that which is now 5 is made the unit. All these meanings, *except the first*, are perfectly intelligible when we write a fraction in which the terms are both fractional. Thus—

$$\frac{1\frac{1}{2}}{3\frac{2}{7}} \qquad \frac{6}{1\frac{1}{3}} \qquad \frac{\frac{1}{3}}{\frac{1}{4}} \qquad \frac{3\frac{2}{7}}{\frac{1}{7}}\text{ , \&c.}$$

may be thus explained. We can readily imagine the part of a time which $1\frac{1}{2}$ is of $3\frac{2}{7}$, the proportion which the first is of the second, and the expression which must be substituted for $1\frac{1}{2}$ when a larger unit is used, amounting to $3\frac{2}{7}$ of the present unit. But though we see clearly what is meant by dividing 1 into 3 equal parts and into 4 equal parts, what idea are we to attach to the division of 1 into $3\frac{2}{7}$ equal parts?

The generality of mathematical conceptions is frequently destroyed by the peculiar idiom of a language. The science of arithmetic requires the abolition of all those distinctions which depend on singular and plural, noun and pronoun, &c. Thus, when we speak of the answer to a problem being a number of feet (unknown), it is better to allow the word to imply a part of a foot, a foot itself, or a number of feet together with a part of a foot, than to repeat all those possible cases every time a number is to be mentioned. Again, when one particular phrase seems absurd, but another which is synonymous appears clear, we must either reject the former altogether, or attribute to it the meaning of the latter, and the second course is generally the more convenient. We now observe that the direction to "divide *one* into 10 equal parts" is the same as "find a part such, that ten of them shall make a unit." Now there is no absurdity in requiring to "find a part such that $3\frac{2}{7}$ of them shall make a unit," though it is inconsistent with our idiom to speak of "dividing 1 into $3\frac{2}{7}$ equal parts." The meaning of the phrase which is intelligible should then be extended to that which is not, or "to divide 1 into $3\frac{2}{7}$ equal parts" should mean that the part is to be found which repeated 3 times and $\frac{2}{7}$ of a time shall give the unit. And this must be extended even to the case in which the number or fraction thus obtained is greater than a unit. Thus in the fourth of the preceding fractions such a number or fraction must be found, that $\frac{1}{7}$th of it shall be a unit; that is,—

$$\frac{1}{\frac{1}{7}} \text{ stands for the number 7;}$$

and this must be repeated $3\frac{2}{7}$ times. The preceding considerations show that fractions with fractional denominators may be explained (without reference to any rule of reduction) by an extension of the definition which applies to integer denominators. The use of such an extension is as follows:—at present, algebraical students learn results which are perfectly intelligible with regard to whole numbers, or to fractions with integer terms, but of which they do not see the meaning when fractional or mixed terms are employed. In the latter case they trust to what they see in the former that their results will remain true; but they can have no distinct perception on this point until they have learnt to include every possible form of $\frac{a}{b}$ under one definition.

The fundamental property of fractions on which all others depend is this—that no fraction is changed in value by multiplying or dividing both its terms by the same number or fraction, that is,—

$$\frac{a}{b} = \frac{ma}{mb}$$

whatever may be the values of a, b, and m. This result should be studied in all the variety of its cases, from such as—

$$\frac{3}{5} = \frac{3 \times 10}{5 \times 10} \text{ to such as } \frac{2\frac{1}{3}}{\frac{17}{7}} = \frac{2\frac{1}{3} \times 1\frac{1}{6}}{\frac{17}{7} \times 1\frac{1}{6}}$$

There is another theorem which is much neglected in elementary works, but which is of considerable importance, namely, that if the numerators of two fractions be added for a numerator, and their denominators for a denominator, the resulting fraction must lie between the two from which it was derived. Thus of the three fractions,

$$\frac{2}{7}\text{ , } \frac{6}{11}\text{ , and } \frac{2+6}{7+11} \text{ or } \frac{8}{18}$$

the third is greater than the first, but less than the second.

In practice it is convenient to employ fractions having either the same denominators, or which may easily be reduced to others of equal value having the same denominators. The numbers 10, 100, 1000, &c., suggest themselves for this purpose: indeed it may immediately be seen that the ordinary system of decimal numeration may be extended so as to allow of a representation of such fractions. If we consider the number 11111, we see that for every step which we make to the right, we find a unit which is only the tenth part of the preceding unit. Place a point *on*[*] the unit's place (to mark its position), and let the same method of valuation be carried further. Then in 11111·1111, the first 1 after the point should stand for one-tenth of the preceding, or one-tenth of a unit; the second for one-tenth of a tenth, or one-hundredth, and so on. The fundamental theorem of decimal fractions, in this view of the subject, is that which shows, for example, that 12·2345 (defined to mean 1 ten, 2 units, 2 tenths, 3 hundredths, 4 thousandths, and 5 ten-thousandths) is the same as 122345 ten thousandths; or that all the number, such as it would be if the units' column were on the right, may be taken as a numerator, and the denomination of the right hand figure as a denominator. Thus—

$$65{\cdot}483 \text{ or } 60 + 5 + \frac{4}{10} + \frac{8}{100} + \frac{3}{1000}$$

$$\text{is } \frac{60000}{1000} + \frac{5000}{1000} + \frac{400}{1000} + \frac{80}{1000} + \frac{3}{1000}$$

$$\text{or } \frac{65483}{1000}$$

No fraction can be reduced to an equivalent decimal fraction, if its denominator contain any prime factor except 5 or 2 (the divisors of ten). But this is of no consequence in practice, since it may easily be shown that for any fraction can be found a decimal fraction which shall be as near to it as we please. For instance, suppose it required to find a decimal fraction which shall not differ from $\frac{3}{41}$ by so much as the hundred thousandth part of a unit. Then—

$$\frac{3}{41} = \frac{300000}{4100000} = \frac{\frac{300000}{41}}{100000} = \frac{7317\frac{3}{41}}{100000}$$

or 7317 hundred thousandths of a unit differs from $\frac{3}{41}$ by only $\frac{3}{41}$ of the hundred thousandth of a unit, or by less than the hundred thousandth part. It is from such a transformation that the common rule is derived.

It is common to say that a result is true to a certain number of places of decimals when any alteration of any place would make it further from the truth. Thus, the diameter of a circle being unity, the circumference lies between 3·1415 and 3·1416, but nearer to the latter; whence the same circumference, true to four places of decimals, is 3·1416. Similarly, 62·13299, taken true to two places, is 62·13; to three, 62·133; to four, 62·1330. Again, ·625, taken true to two places, might be either ·62, or ·63; but the latter is generally taken. When a decimal fraction cannot be found exactly equal to a given common fraction, the division by which the numerator is found, leads to what is called a CIRCULATING DECIMAL.

For subjects closely connected with the theory of fractions, see RATIO; PROPORTION; INCOMMENSURABLE.

FRACTIONS, CONTINUED. A continued fraction is one which has a fraction in its denominator, which again has a fraction in its denominator, and so on: such as

$$\cfrac{1}{2 + \cfrac{3}{7 + \cfrac{6}{1 + \cfrac{2}{3}}}}$$

A more convenient way of writing such fractions is desirable; in the present article we shall adopt the following:—

$$\frac{1}{2 +}\,\frac{3}{7 +}\,\frac{6}{1 +}\,\frac{2}{3}$$

$$\text{Thus } \cfrac{a}{b + \cfrac{c}{d + \cfrac{e}{f}}} \text{ is written } \frac{a}{b +}\,\frac{c}{d +}\,\frac{e}{f}$$

The use of continued fractions is as follows: by converting a common fraction with a large numerator and denominator, into a continued fraction, we are able to find a succession of more simple fractions which are alternately greater and less than the given fraction, and approach to it with great rapidity. Let $\frac{a}{b}$ be the given fraction, a being less than b; proceed as in the rule for finding the greatest common measure of a and b, and let q, r, s, t, &c., be the quotients obtained in the process; then

$$\frac{a}{b} = \cfrac{1}{q + \cfrac{1}{r + \text{\&c.}}} \qquad \text{or } \frac{1}{q +}\,\frac{1}{r +}\,\frac{1}{s +}\,\frac{1}{t +} \text{ \&c.}$$

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[*] It will be very useful to the student to remember that this decimal point *belongs to the unit's place*, and is not an introduction *between* the integers and the fractions.

For instance, let the fraction be $\frac{5119}{28319}$

$$\left.\begin{array}{r} 5119)28319(5 \\ \text{Rem. } 2724)5119(1 \\ 2395)2724(1 \end{array}\right\}$$
&c., as in the method of finding the greatest common measure.

The succession of quotients thus obtained is

5, 1, 1, 7, 3, 1, 1, 2, 1, 3, 1, 2;

which are to be used as follows in forming the succession of approximate fractions. The first and second are always

$$\text{1st } \frac{1}{\text{first quotient}} \text{ in this case } \frac{1}{5}$$

$$\text{2nd } \frac{\text{2nd quotient}}{\text{1st qu.} \times \text{2nd qu.} + 1} \text{ . . . . . } \frac{1}{5 \times 1 + 1} \text{ or } \frac{1}{6}$$

To form the succeeding numerators and denominators there is one uniform rule for both, as follows: Multiply the last found term by the first quotient remaining to be used, and add the last but one; as in the following process, where (*) denotes that the incoming quotient is unity, and that the multiplication is therefore unnecessary.

	Numerators.	Denominators.
1st	1	5
2nd	1	6
3rd*	2	11
New quotient	7	7
	14	77
	1	6
4th	15	83
New quotient	3	3
	45	249
	2	11
5th	47*	260*
	15	83
6th	62*	343*
	47	260
7th	109	603
New quotient	2	2
	218	1206
	62	343
8th	280*	1549*
	109	603
9th	389	2152
New quotient	3	3
	1167	6456
	280	1549
10th	1447*	8005*
	389	2152
11th	1836	10157
New quotient	2	2
	3672	20314
	1447	8005
12th	5119	28319

The succession of fractions continually approximating to the given fraction, and ending in it, is then

$$\frac{1}{5}, \frac{1}{6}, \frac{2}{11}, \frac{15}{83}, \frac{47}{260}, \frac{62}{343}, \frac{109}{603}, \frac{280}{1549}, \frac{389}{2152}, \frac{1447}{8005}, \frac{1836}{10157}, \frac{5119}{28319};$$

these approach nearer and nearer to the last, than which they are alternately greater and less; the first greater, the second less, the third greater, and so on; but the second is not so much too small as the first is too great, nor the third so much too great as the second is too small, &c. The error committed by assuming any one of the approximate fractions instead of the final result, is less than a fraction having unity for its numerator, and the product of the denominator in question and the next denominator for its denominator. Thus—

$$\frac{1}{5} \text{ is not wrong by } \frac{1}{5 \times 6} \text{ or } \frac{1}{30}$$

$$\frac{1}{6} \text{ ,, ,, } \frac{1}{6 \times 11} \text{ or } \frac{1}{66}$$

$$\frac{2}{11} \text{ ,, ,, } \frac{1}{11 \times 83} \text{ or } \frac{1}{913}$$

$$\frac{15}{83} \text{ ,, ,, } \frac{1}{83 \times 260} \text{ or } \frac{1}{21580}, \text{ \&c.}$$

If it be desired to verify one of the fractions without proceeding to the end of the process, observe that the numerator of the difference of any two succeeding fractions is unity. Thus—

1 × 6 exceeds 1 × 5 by 1
1 × 11 falls short of 2 × 6 by 1
2 × 83 exceeds 15 × 11 by 1
15 × 260 falls short of 83 × 47 by 1 &c.

No fraction, having a less denominator than one of the approximate fractions, can come so near to the original fraction as the one which is obtained by the process. Thus, $\frac{109}{603}$ is nearer to $\frac{5119}{28319}$ than any possible fraction which has an integer numerator, and an integer denominator less than 603.

FRACTIONS, DECOMPOSITION OF, a method of much use in the integral calculus for reducing products of the form $\mathrm{X}(x-a)^{-m}(x-b)^{-n}$ . . . . . in which X is rational and integral, to the sum of terms of the form $\mathrm{K}(x-a)^{-k}$, in which K is independent of x. But if X be of a higher dimension than $m+n+$ . . . there is also a quotient.

This quotient may be easily found by the short rule for division by $x-a$. To divide $px^m + qx^{m-1} +$ . . . by $x-a$, take the first coefficient, multiply it by a and add the next; repeat this process to the end, taking care to use 0 for the coefficient of any missing term. The results, beginning with the first coefficient, are the coefficients of the quotient, except the last, which is the remainder. Thus in dividing $2x^7-2x^6+x^3+x-1$ by $x-3$, the coefficients are

2 −2 0 0 1 0 1 −1

The results of the rule are

2 4 12 36 109 327 982 2945

Hence the quotient is $2x^6+4x^5+12x^4+36x^3+109x^2+327x+982$, and the remainder is 2945. To divide by $x+a$, or $x-(-a)$, use $-a$ as a multiplier.

Thus to find the quotient of x^8-2x^3+4 divided by $(x-1)^3(x+1)^2(x-5)$, the process is as follows, it being seen beforehand that the answer is of the second degree. We omit all the work which is of no use in the final result.

```
1   0   0
1   1   1
1   2   3
1   3   6
1   2   4
1   1   3
1   6  33
```

When we divide x^8-2x^3+4 by $x-1$ the three first terms of the quotient are $x^7+x^6+x^5$: two divisions more by $x-1$ give $x^5+3x^4-6x^3$. We then divide twice following by $x+1$, still preserving only three terms, and the result is x^3+x^2+3x, and the final division by $x-5$ brings out $x^2+6x+33$ for the three first terms of the final quotient, that is, for the whole quotient. For verification the order of the divisions may be varied.

When all the roots of the denominator are unequal, that is, when the quantity to be reduced is of the form $\mathrm{X}(x-a)^{-1}(x-b)^{-1}(x-c)^{-1}$ . . . . where a, b, c, &c., are all unequal, the process for finding the reduced form of the remainder is very easy. Strike out $(x-a)^{-1}$ and make $x=a$ in the form thus mutilated; let this result be A. Next strike out $(x-b)^{-1}$, and make $x=b$; let the result be B; and so on. Then the fraction $\mathrm{X}(x-a)^{-1}(x-b)^{-1}$ . . . . is the quotient, if any, $+\mathrm{A}(x-a)^{-1}+\mathrm{B}(x-b)^{-1}+$ . . . . Thus to reduce the expression $x^6 \div (x-1)(x-2)(x+1)$, we set down all the work, as follows; the quotient being of the third degree—

$$\begin{array}{cccc} 1 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 \\ 1 & 3 & 7 & 15 \\ 1 & 2 & 5 & 10 \end{array} \qquad \begin{array}{r} 1^6 \div (-1 \times 2) = -\frac{1}{2} \\ 2^6 \div (1 \times 3) = \frac{64}{3} \\ (-1)^6 \div (-2 \times -3) = \frac{1}{6} \end{array}$$

And the final result is

$$\frac{x^6}{(x-1)(x-2)(x+1)} = x^3+2x^2+5x+10$$

$$-\frac{1}{2}\frac{1}{x-1} + \frac{64}{3}\frac{1}{x-2} + \frac{1}{6}\frac{1}{x+1}$$

When the roots of the denominator are not all equal, the way of proceeding which is most easy in the simple cases which generally occur in practice, will be best caught from an example. Suppose, for instance, that $(x^4+1) \div (x-1)^2(x-2)(x+1)$ is the fraction to be reduced. Begin with the denominator $(x-1)(x-2)(x+1)$, and by the preceding rule, obtain the result,

$$\frac{x^4+1}{(x-1)(x-2)(x+1)} = x+2-\frac{1}{x-1}+\frac{17}{3}\frac{1}{x-2}+\frac{1}{3}\frac{1}{x+1}$$

Divide both sides by $(x-1)$, and turn $(x+2)\div(x-1)$ into $1+3\div(x-1)$, and also by the rule, convert

$$(x-1)^{-1}(x-2)^{-1} \text{ into } -(x-1)^{-1}+(x-2)^{-1}$$

$$(x-1)^{-1}(x+1)^{-1} \text{ into } +\frac{1}{2}(x-1)^{-1}-\frac{1}{2}(x+1)^{-1}$$

and the result is

$$\frac{x^4+1}{(x-1)^2(x-2)(x+1)}=1-\frac{15}{6}\frac{1}{x-1}-\frac{1}{(x-1)^2}$$
$$+\frac{17}{3}\frac{1}{x-2}-\frac{1}{6}\frac{1}{x+1}$$

More complicated examples may be seen in the 'Differential Calculus' ('Library of Useful Knowledge'), p. 273. The above will be sufficient for ordinary purposes.

FRACTIONS, VANISHING. This term is applied to fractions in cases where a supposition is made which destroys both numerator and denominator at the same time. Thus:

$$\frac{x^2-1}{x-1} \qquad \frac{\text{log. } x}{x-1}, \qquad \frac{a^x-a}{b^x-b},$$

are fractions which all assume the form $\frac{0}{0}$, when $x=1$; that is, though for any other value of x they represent operations of ordinary arithmetic, yet in the particular supposition that x is unity, they all end in a direction to find out how many times *nothing* is contained in *nothing*. The first answer to this seems to be that the fraction may, in such a case, have any value we choose to assign, for nothing taken once, or twice, or thrice, &c., is still nothing: that is to say, according to the rules of common algebra, since $0=0\times a$, whatever a may be, it follows that 0 divided by 0 may be a. But this is carrying operations which are defined with regard to magnitudes further than is contemplated in their definition, and applying them to a symbol which simply represents the absence of all magnitude. Such a process may then be rejected without scruple.

But this question remains: granting that the preceding reasoning does not entitle us to give the preceding fractions any value we please, can they be said to have a value at all when $x=1$? To settle this point in part, we must ask not what the preceding fractions are when x is unity, but what becomes of their value when x is made to approach nearer and nearer to unity. To take the first as an instance, we find that

$$\frac{x^2-1}{x-1}=x+1 \text{ for all } \textit{values} \text{ of } x.$$

Consequently—I. Whenever x is greater than 1, the fraction is greater than 2. II. As x approaches to 1, the fraction approaches to 2. III. The fraction may be made as near to 2 as we please by making x sufficiently near to unity. Hence it follows that if when $x=1$, the fraction have a value at all, that value must be 2. Similarly it may be proved of the second and third fractions, that if they *have* values when $x=1$, these values must be 1 and $\frac{a \log a}{b \log b}$.

Much discussion has arisen as to whether vanishing fractions have values or not, as if such a question could be one of deduction from the ordinary reasonings with regard to magnitude. The truth is, that any one may either assert that such fractions have values, or may altogether refuse to consider them, according to his ideas of convenience or propriety. Nobody doubts that if the answer to a problem were

$$\text{'}y=\text{the value of } \frac{\log x}{x-1} \text{ when } x=1,\text{'}$$

one of two courses must be taken: either the value of y must be declared to be unity, or else the evanescent form of the fraction must be recognised as arising from a misconception of the problem, by which factors of the form $x-1$ (where $x=1$) have been used under the idea that they were of the form $x-1$ (where x is not $=1$): the problem must then be reconsidered, and the (so called) mistake corrected. But the correction will always lead to the result $y=1$, and those who employ the second method in preference to the first will not deny that they knew as much when they first saw their (so called) erroneous result.

It is not worth while to discuss the particular arguments used with respect to the isolated question of vanishing fractions, since the difficulty raised with regard to them belongs to a class of questions so extensive that they might form the subject of a separate science. Under the heads NOTHING, INFINITY, LIMITS (THEORY OF), &c., will be found those considerations which apply to all the cases.

The method of finding the value (or correction, if the reader please) of a vanishing fraction whose numerator and denominator disappear when $x=a$, is to make a new fraction with the differential coefficients of that numerator and denominator, and then to substitute a for x. If the result be still a vanishing fraction, repeat the process with new differentiations, and so on. Thus, to find the value of the third fraction above mentioned,—

$$\text{diff. co. of } a^x-a \text{ is } a^x \log a$$
$$\text{diff. co. of } b^x-b \text{ is } b^x \log b$$
$$\frac{x^x \log a}{x^x \log b}, \text{ when } x=1, \text{ is } \frac{a \log a}{b \log b}.$$

FRACTURE. Injuries complicated with the breaking of a bone are called fractures.

The comparative importance of such accidents depends in the first place upon that of the bone which is broken. The most dangerous fractures in this point of view are those of the vertebræ and skull, which inclose organs immediately essential to life, and extremely susceptible of injury. The *processes*, or projecting parts, of the vertebræ are sometimes broken without very serious consequences; but if any of the rings of bone which encompass the spinal cord be thus injured, death almost certainly ensues, and the danger is imminent in proportion to the nearness of the injured vertebra to the head. If the fracture take place above the fourth vertebra of the neck, reckoning downwards, death is generally instantaneous from paralysis of the nerves of respiration. Fracture of the *basis* or floor of the skull is often instantly fatal, for analogous reasons. The *sternum*, or breastbone, and ribs, cover parts not so immediately essential to life, and, for many reasons, not so liable to suffer from violence done to their external defences as those to which we have already adverted. Fracture of the sternum can scarcely happen without the direct application of considerable force; and for that reason is both serious and rare. The ribs, on the contrary, are more easily and frequently broken than any other bones; and generally speaking the consequences are not at all serious, if proper measures be adopted. The fracture unites readily; and the chief danger to be apprehended is inflammation of the serous membrane called the *pleura*, which lines the cavity of the chest, or of the lung. [PLEURISY; PNEUMONIA.] This danger is of course increased if the lung be wounded by the splintered ends of the bone, which is sometimes the case, especially when the fracture is the result of direct force. The bones of the pelvis are seldom broken, for the same reason that determines the rare occurrence of fracture of the sternum; but the accident is generally serious, and not unfrequently fatal, from injury to the bladder and other important organs included in the pelvic cavity, or connected with the bones which circumscribe it. Fractures of the bones of the face, though distressing and painful at the time, generally do well; and are of consequence chiefly on account of the disfigurement they sometimes occasion.

The limbs are so essential to the purposes of life, and their usefulness depends so much upon the preservation of the shape of their numerous bones, upon the integrity of their joints, and upon the free and separate mobility of their muscles and tendons, that anything calculated to injure them permanently in these particulars is a matter of serious importance. Hence the great interest that has always been attached to fractures occurring about these parts; none of which can be considered as slight accidents, for in various degrees they all threaten the future usefulness of the limb.

We feel that the subject of fracture, particularly of the limbs, is one that hardly admits of compression within moderate limits; and are aware that in attempting to compress it we must sacrifice order, if not perspicuity, to brevity. Our principal object, however, will be to give a clear explanation of certain technical terms, by which important varieties of these injuries are distinguished; and which, though frequently made use of in conversation and in the course of judicial proceedings, are often misapplied or imperfectly understood: with this we shall interweave as much general information as possible, subjoining what may be necessary to complete an outline of the whole subject.

It can hardly be necessary to explain what is meant by *transverse* and *oblique* fracture: we may observe, however, that the distinction is practically of great consequence. In the first, or *transverse* variety, the bluntness of the ends of the broken bone in some measure preserves the contiguous soft parts from laceration at the time of the accident; it also opposes a considerable obstacle to the displacement which arises afterwards from muscular contraction; but it chiefly conduces both to the diminution of present suffering and to the prosperous event of the case, by facilitating the speedy and perfect restoration of the displaced bone to its proper situation, and its steady retention, when restored, by mechanical means.

On the other hand, as most of the bones liable to fracture are cylindrical, or present flattened surfaces meeting in as many solid angles, if they be broken obliquely, the ends of the bone will be sharp-edged or pointed: hence they are generally separated from each other to a much greater extent than is usual in transverse fracture, and there is not only much more suffering from the laceration of sensitive parts and from portions of them being included and pressed between the broken surfaces, but great difficulty is often experienced in disentangling the ends of the bone, and bringing them into close apposition; and still more in retaining them, from their tendency to slip past each other during the spasmodic and powerful contractions of the wounded and irritated muscles. The result of such fractures is often unsatisfactory, in spite of the utmost care and skill; and some distortion and shortening of the limb is inevitable in severe cases.

Comminuted Fracture.—When a bone is crushed, or fissured in more than one direction, so that portions of it are detached from the rest, the fracture is said to comminuted. From the facility generally experienced in replacing the bone, or at least in straightening and supporting the limb in these cases, they often end better than apparently less serious oblique fractures. Perhaps one reason may be that the direct application of force, by which they are generally produced, has some effect in stunning the muscles and deadening the injurious influence of their contraction. If there be much contusion of the soft parts, considerable inflammation and fever may supervene, and the recovery will be tedious in proportion; but the eventual restoration of the natural shape and length of the limb is frequently more complete than might be expected.

Fracture extending into a joint.—A bone may of course be broken in the situation of a joint; or, if the fracture occur at some distance, a fissure may extend longitudinally into one of these cavities. This circumstance is a very important aggravation of the injury. The synovial membranes which line the joints are peculiarly impatient of irritation, and when they become inflamed, the constitutional disturbance is often considerable, and the attendant, or, as it is called, the *symptomatic* fever, is of a very acute type. When the larger joints, such as the knee, are concerned in injuries of this kind, the old surgeons frequently recommended amputation of the limb. Modern experience has shown that this may generally be dispensed with; but the greatest skill and watchfulness are required and often baffled in endeavouring to prevent the occurrence of a stiff joint (*anchylosis*), and to keep the limb in the most useful position, if it should occur; a position which is not always the most conducive to the case, or indeed to the recovery, of the patient, and therefore not always eligible.

Fracture complicated with dislocation.—If a bone be dislocated as well as broken, it may be difficult or impossible to carry into effect the measures which are necessary for the satisfactory treatment of either injury, and the result is permanent distortion and crippling of the limb. This is of course an extreme case, and is not likely to happen unless the fracture take place very near the dislocated joint, so that a firm hold cannot be taken of the detached end of the bone. If, however, the fissure in the bone does not extend to the joint, the constitution does not, upon the whole, suffer so materially as might be expected in consequence of the double injury, except in particular cases, such as those complicated with traumatic delirium, on which, as the subject is curious, we shall here take occasion to say a few words.

Traumatic delirium (*τραῦμα, a wound*).—This affection is by no means confined to fractures with dislocation, or to injuries of which fracture forms a part. It appears however to be more frequently a consequence of injuries of this nature than of others, and particularly of the fracture of the fibula immediately above the ancle, which is often followed by dislocation of the foot. [Fibula, in Nat. Hist. Div.] The patient rambles in his ideas, is generally very talkative, and in a state of great alarm and apprehension, expecting, for instance, to be led to execution for some fancied crime. He is commonly pale and cold, free from fever, and quite unconscious of pain. If not prevented, he will rise from his bed and move about the room, using his shattered limb with perfect unconcern. Traumatic delirium has some points of resemblance with delirium tremens, and like it, occurs for the most part in over-stimulated and exhausted constitutions. It is sometimes fatal, but may generally be relieved by large quantities of wine and opium.

Compound fracture.—If the injury of which we are treating be confined to the bones and the parts immediately around them, the fracture is said to be *simple*; but if the bone be protruded through the skin, or an external wound otherwise inflicted communicate with the interval between the broken surfaces, the fracture is said to be *compound*. However small the wound in the skin may be,—unless it can be brought to heal by the first intention, which, though it rarely succeeds, should be always attempted,—this is by far the most serious aggravation of the injury, whether we regard the suffering of the patient, the progress of the case, or the prospect of recovery. A simple fracture, however extensive, if not into a joint, may generally be expected with confidence to be well enough to permit the accustomed use of the limb in a period ranging from two to eight weeks; the pain and constitutional derangement seldom lasting beyond a few days. But a compound fracture threatens life, and, speaking generally, is at best an affair of many months of suffering and sickness. This remarkable difference originates in the wide constitutional sympathies of the skin as an organ of sensation and secretion; in the importance of its function as a covering for the subjacent parts; and in its great proneness to become inflamed when the subject of a punctured and lacerated wound. It further results from the tendency of the inflammation to propagate itself from the edge of the skin along the track of the wound to the periosteum and other deep-seated parts; it commonly spreads very extensively in cellular tissue between the muscles, under the aponeurotic expansions which invest and separate them, and within the synovial sheaths of their tendons. Some degree of inflammation among these parts takes place in simple fractures, but it seldom exceeds manageable limits and the lower degrees of it may perhaps be considered as curative. But the inflammation which follows a compound fracture puts a stop to all the natural processes of restoration, and renders the artificial means, in other cases usefully employed to promote them, ineffectual or inapplicable. It is attended with incessant and exhausting fever, at first ardent and afterwards irritative and hectic [Fever], and occasions deep-seated abscesses, extensive destruction of the soft parts (*sloughing*), and tedious separation of dead bone (*exfoliation*). Such are some of the disastrous consequences of a compound fracture, an accident which, in its severer forms, presents such a scene of suffering and a succession of such formidable drains upon the strength, that, on the balance of evils, amputation is often a preferable alternative.

Diagnosis of fracture.—Much need not be said of the means by which the existence of a supposed fracture may be ascertained. The nature of the accident is generally obvious enough, and the less the parts are handled the better; but where there is any doubt, it may be removed by attending to the grating sound, or the sensation communicated to the touch occasioned by slightly moving the broken ends of the bone against each other. This symptom is called *crepitation*.

Treatment.—The principles of treatment are, in the first place, to soothe by all possible and prudent means the muscular irritation and spasm which are the immediate and most urgent consequences of a recent fracture. The patient is to be placed in the easiest posture, which, if the thigh or leg be broken, is generally on the same side or on the back; the limb is to be supported on soft pillows, the contiguous joints being half-bent in order to favour as much as possible the relaxation of each class of muscles, especially the flexors; gentle friction, warm fomentations, or cold evaporating lotions are to be used according to the circumstances of the case and the feelings of the patient.

When the relaxing rigidity of the muscle will permit, which may not be for some hours or days, the bone is to be restored as nearly as possible to its proper situation by the gentle application of force in any required direction. Violence would defeat its own object by reproducing spasm. One hand or an assistant should steady the upper portion of the limb while the lower portion is drawn down and turned till the proper length and bearings are restored. This process, which is called the *reduction* or *setting* of the fracture, cannot always be completed on the first attempt; and it is sometimes advisable, and indeed only possible, to effect it by degrees. The displacement may also return; and in oblique fracture this will certainly happen unless the case admits of a very fortunate adjustment of the bandages. The process we have described must then of course be repeated as often as circumstances may render it necessary. The setting of a broken limb is not, as people generally imagine, a piece of legerdemain, to be effected in a moment by some wonderful exertion of dexterity, and then to be announced in oracular phrase by the surgeon as if it were something too mysterious for a plain man to understand. It is a perfectly simple and straightforward measure; and little more than common sense and a gentle hand are necessary for its proper execution if it be possible to effect it at all.

When the limb is reduced, it is to be placed in *splints*, which are thin pieces of wood or other material of the requisite firmness and length, and suitably shaped and hollowed out to fit evenly without making undue pressure upon prominent points, such as the ankle. The skin is to be protected by folds of linen or thin soft pads a little wider than the splints, which are also useful to prevent them from slipping. When everything is properly arranged as to position, the splints are to be bound upon the limb with a moderate degree of pressure; and it is right to remove and re-adjust them occasionally, in order to detect and rectify any deviation from the correct line of the bone that may arise or become apparent as the swelling subsides.

Where there is no fear of the bone being displaced by the action of the muscles that are attached to it, or by the restlessness of the patient, it is not necessary to apply splints, which are only useful in preventing motion, and otherwise rather retard the progress of the case by their pressure, and for other reasons.

In fracture of the ribs, it is sufficient to apply a broad belt or bandage to prevent them from alternate depression and elevation in the act of breathing, which can be carried on sufficiently well by the diaphragm alone [Respiration, in Nat. Hist. Div.]; and all such means are inapplicable in many cases, such as fracture of the vertebræ, and of the neck of the thigh-bone, where all that can be done of a mechanical kind is to place and keep the patient in a proper position. This can be done most effectually by the help of a bedstead invented by Mr. Earle, the frame of which is jointed, so that the back may be raised to any required inclination, the knees being also raised, and the feet, if necessary, bound to a cross-board. The mattrass is provided with moveable pieces, which preclude the necessity of change of position for any purpose. The paramount importance of constitutional treatment and a strict regulation of the diet need scarcely be adverted to in this as in all cases of injury, in which a primary object is to repress or prevent inflammation.

Union of fractured Bone.—The process by which fractured bones are united is generally uninterrupted in simple cases, if the constitution be good and the accompanying contusion not very considerable. The extravasated blood is soon absorbed, and the swelling and inflammation subside. The interior lacerations heal, and the soft parts round the ends of the fracture become consolidated with the periosteum, or fibrous investment of the bone, which swells and unites at the torn edge. In this consolidated mass, which forms a soft case for the bone for some distance above and below the fracture, but is thickest just at that point, particles and spicula of bone are gradually deposited, till at length it becomes rigid and firm, holding the ends of the bone in close contact and peventing them from slipping away from each other, like the slider of a parasol. At length the patient finds the strength of his limb restored, and conscious of the change, can no longer be persuaded to refrain from using it. After a certain period, which has been differently stated—it may be six or seven months in the case of a large bone—the fractured ends become firmly adherent by the deposit of bony matter between them; the exterior case becomes absorbed, and the cure is complete, the bone being rather thicker and generally somewhat stronger and more solid in the situation of the fracture than before the accident. The whole of this process is much quicker in infants and children than in adults, and somewhat more slow in advanced periods of life than in the middle age. Taking all ages, it ranges, as we have said, from two to eight or ten weeks—speaking, of course, of the period at which the limb becomes firm enough to perform its functions.

The treatment and progress of compound fracture depend upon the circumstances of each case; and it would lead us too far to enter upon them. The principles of management, however, are the same, as are likewise, in the main, the natural processes by which firm union is established.

Ununited Fracture.—It sometimes happens that, without any assignable cause, the processes we have just spoken of do not go forward; and the fracture, originally perhaps a very simple and promising one, either does not unite at all, or unites only by a tough and flexible substance like ligament or tendon; and this even where nothing faulty can be discovered in the constitution of the patient, or in the management of the surgeon. Attempts are made to excite irritation and promote the deposition of bony matter in this new substance by rubbing the ends of the bone together, and in other ways. Such attempts not unfrequently fail, and the bone remains flexible and useless for life.

Causes of Fracture.—We have said nothing of the various ways in which fractures may accidentally take place, because each reader can imagine them for himself. There are, however, some circumstances with reference to this subject which it is proper to mention. In the first place, the simple action of the muscles, without any blow or external pressure, is sufficient to break the bones. Such is, generally speaking, the case in transverse fractures of the *patella* or knee-pan, and occasionally in those of the *olecranon*, or point of the elbow. When these are broken off by a sudden jerk of the muscles attached to them, the detached portion of bone is carried up to some distance, and can rarely be brought into sufficiently close apposition to unite by bony matter. But the ligamentous substance we have mentioned in speaking of ununited fracture is formed between the broken surfaces; and if proper care be taken not to permit it to be stretched while it is yet soft and extensible, it answers every purpose in these cases nearly as well as bone. When one patella has been broken in this way, the other is almost sure to follow soon after, having a double duty to perform in supporting the muscular contraction by means of which the thigh is brought to a straight line with the leg in the erect posture.

Imperfect Fracture.—There are some conditions which modify the liability to the occurrence of fractures. Among these may be mentioned the soft and cartilaginous state of the bones in young infants before the earthy matter has been completely deposited. At this period it is not uncommon to find that although the limb is flexible at a certain point, no crepitation can be felt, and that in point of fact there is no actual separation of the ends of the bone. This is called *imperfect* fracture.

The opposite state of brittleness prevails in old age; and owing to this circumstance, a very slight accident will often cause a fracture of the neck of the thigh bone, the soft parts commonly receiving little injury. In these instances ligamentous union is all that can be effected, and the limb remains for the remainder of life to a great degree crippled.

Fragilitas Ossium.—A still more brittle condition of the bones is sometimes co-existent with cancer, and probably other morbid states of the constitution. It is called *fragilitas ossium* (fragility of the bones), and sometimes reaches a remarkable pitch. A late eminent physician informed the writer that, being called to attend upon a lady in her pew at church, he found that she had broken her thigh in rising from her hassock; and in attempting to raise her, he broke her arms. There is generally little injury of the soft parts in these fractures, and they are said to unite rather more quickly than others.

Some persons have asserted that the bones are more brittle in winter than in summer; but it does not require an hypothesis so improbable as this to explain the principal fact on which the proof has been rested, namely, the more frequent occurrence of fractures in frosty weather.

FRAISE is a row of palisades placed in a horizontal or oblique position on the exterior, or on the edge of the ditch, in order to increase the difficulty of passing over it at the time of an assault.

FRAMBÆSIA. [Skin, Diseases of.]

FRANCHISE, a species of incorporeal hereditament. Franchise and liberty are used as synonymous terms, and their definition is a royal privilege, or branch of the prerogative, subsisting in the hands of a subject. Such privileges must arise, therefore, from the grant of the crown, though in some cases they may be held by prescription, which presupposes a grant. The kinds of them are various, and almost infinite, and may subsist in corporations, in one man, or in many, as co-tenants. Thus a county palatine is a franchise, and so are privileges given to corporate bodies, forests, chases, the right to wreck, estrays, &c. Franchises may be lost or forfeited by the parties who enjoy them, if they misuse their privilege or neglect to perform the requisite duties in respect of them [Ferry]; and if the owners are disturbed or incommoded in the proper exercise of their franchise, which is an injury known to the law as a disturbance of franchise, they may have remedy in an action, or where the franchise is to levy a toll, they may distrain for the amount alleged to be due.

FRANCISCANS. In the Biographical Division an account of the chief order is given under Francis, St.; and it is there stated that even of these there was considerable diversity in the practice of the rules of the order. One part, called Spirituals, contended for the observance of the rules in all their strictness; the others, called Conventuals, advocated the possession of property to any extent by the body as a community, though still professing poverty as individuals. The Popes were partisans now of one branch and now of the other, during the 15th and 16th centuries; and various ineffectual attempts were made to efface the differences. The Fratricelli [Fratricelli] entirely separated from them in the 15th century, or rather founded a new order, adopting the primitive rules of St. Francis. As early as 1294 a number separated themselves, and formed a sub-order called Celestin Hermits, or Minorites; but this order was suppressed early in the 14th century by the efforts of the Inquisition. In 1302 the Clare Brethren also formed a separate sect, who, after some time took the name of Observantins. To this order belonged the nuns of St. Clare (as they were erroneously called, for the name was derived from a river in Spain, where the first establishment was formed), or Minoresses, whose nunnery was in London, near Tower Hill. In 1525 a new secession ended in the establishment by Pope Clement VII. in 1528 of the order of *Capuchins*, so called from the pointed cowl or capuche which they added to the ordinary Franciscan habit. The Capuchins professed an abstinence from all worldly pleasures, and by their humility, gravity, and attention to their duties, ultimately acquired great popularity and influence, though they had to struggle for a long time against the power and influence of the Franciscans for their very existence. In 1619 they acquired the right of electing their own general, who held office for three years. Nuns of this order were first instituted at Naples in 1583. During the early part of the present century the order was suppressed, and the possessions secularised, in all the Roman Catholic countries of Europe, except Portugal, Spain, and Sicily; but since 1814, settlements of the order have been made in Italy, Germany, and other places. Another sect was formed in 1532, by the authority of the Pope, called Reformed Franciscans in Italy, Recollets in France, and Barefooted Franciscans in Spain. They were also known as Friars Minors of the Strict Observance, from their rigid adherence to the original rules of the order. Other orders of less note were the Brothers of the Sack, and the Bridgetine Nuns.

FRANKALMOIGNE. This tenure is thus described by Littleton (§ 133): "Tenant in Frankalmoigne is when an abbot or prior, or other man of religion, or of holy church, holdeth of his lord in Frankalmoigne; that is to say, in Latine, *in liberam eleemosinam*, that is, in free almes. And such tenure beganne first in old time." From this it appears that lands which are held by religious bodies or by a man of religion, are held by this tenure; but neither fealty nor any other temporal service is due. The spiritual services which were due before the Reformation are thus described by Littleton (§ 135): "And they which hold in frankalmoigne are bound of right before God to make orisons, prayers, masses, and other divine services for the souls of their grantor or feoffer, and for the souls of their heires which are dead, and for the prosperity and good life and health of their heires which are alive. And therefore they shall do no fealty to their lord; because this divine service is better for them before God than any doing of fealty; and also because these words (frankalmoigne) exclude the lord to have any earthly or temporal service, but to have only divine and spiritual service to be done for him."

On this section Coke remarks: "Since Littleton wrote, the liturgie or Book of Common Praier of celebrating divine service is altered. This alteration notwithstanding, yet the tenure in frankalmoigne remaineth; and such prayers and divine service shall be said and celebrated as now is authorised; yea, though the tenure be in particular, as Littleton hereafter (§ 137) saith, namely, to sing a mass, &c., or to a *placebo et dirige*, yet if the tenant saith the prayers now authorised, it sufficeth. And as Littleton hath said before (§ 119), in the case of socage, the changing of one kind of temporall services into other temporal services altereth neither the name nor the effect of the tenure; so the changing of spiritual services into other spiritual services altereth neither the name nor the effect of the tenure. And albeit the tenure in frankalmoigne is now reduced to a certaintie contained in the book of Common Prayer, yet seeing the original tenure was in frankalmoigne, and the change is by general consent by authority of parliament, whereunto every man is party, the tenure remains as it was before."

The statute 12 Charles II., which abolished military tenures, expressly excepts tenures in frankalmoigne.

Those who hold lands in frankalmoigne must do the services for which these lands were given. These services are now determined, as Coke says, by the book of Common Prayer. The mode of compelling these tenants to do their duty is thus described by Littleton (§ 136) "And if they which hold their tenements in frankalmoigne will not, or fail to do such divine service (as is said), the lord may not distrain them for not doing this, &c., because it is not put to certainty what services they ought to do. But the lord may complain of this to their ordinary or visitor, praying him that he will lay some punishment and correction for this, and also provide that such negligence be no more done, &c. And the ordinary or visitor of right ought to do this," &c.

Since the statute of 18 Ed. I., called *Quia Emptores*, from the introductory words, there can be no gift in frankalmoigne except by the crown. This tenure, however, as Blackstone observes, "is the tenure by which almost all the ancient monasteries and religious houses held their lands; and by which the parochial clergy and very many ecclesiastical and eleemosynary foundations hold them at this day, the nature of the service being upon the Reformation altered, and made conformable to the purer doctrine of the Church of England."

FRANKINCENSE, Common, obtained from *Abies excelsa* (Dec.), the *Pinus abies* of Linn., consists of two kinds of resin mixed with oil of turpentine. By melting it in water, and straining it through strong cloths, it is deprived of much of its oil, when it is termed pix arida, or Burgundy pitch, and also white resin.

It is scarcely now used internally, but is irritant and diuretic. Externally it is rubefacient, and consequently enters into the composition of many plasters.

FRANKLIN. In the reign of Elizabeth a franklin was a freeholder, or yeoman, a man above a vassal or villain, but not a gentleman. He is mentioned as of this description in several passages of Shakspere's plays. In earlier times he was a personage of much more dignity, and seems to have been distinguished from a common freeholder by the greatness of his possessions. Chaucer's franklin (Introduction to 'Canterbury Tales') was a rich and luxurious gentleman, a chief man at the sessions, and had been sheriff, and frequently knight of the shire.

Fortescue, 'De Legibus Angliæ,' c. 29, describes the franklin as "Pater familias—magnis ditatus possessionibus."

FRANKPLEDGE. [Leet.]

FRATRICELLI, or Little Brethren, (an Italian translation of Fratres minores, or Friars Minors as the Franciscans called themselves) also called *Fratres de paupere vitâ*, a religious sect which arose in Italy towards the end of the thirteenth century. They were Franciscan monks who separated themselves from the grand community of St. Francis with the intention of obeying the laws of their founder in a more rigorous manner than they were observed by the other Franciscans. They accordingly renounced every kind of property, both common and individual, and begged from door to door their daily subsistence, alleging that neither Christ nor his Apostles had any possessions, either individual or in common; and that these were the models which St. Francis had commanded them to imitate. They went about clothed in rags declaiming against the vices of the pope and the bishops, thus preparing the way for the Reformation, and foretold the purification of the church and the restoration of the true gospel of Christ by the real followers of St. Francis. As the Franciscan order acknowledges for its companions a set of men who observe the third rule prescribed by St. Francis, and were therefore commonly called Tertiarii; the order of the Fratricelli had a great number of Tertiarii attached to their cause. These tertiarii, or half monks, were called in Italy *Bizochi* or *Bocasoi*, in France *Beguins*, in Germany *Begwards* or *Beghards*. The Tertiarii differed from the Fratricelli, not in their opinions, but only in their manner of living. The Fratricelli were real monks, subject to the rule of St. Francis, whilst the Bizochi or Beghards, as well as the Franciscan Tertiarii, excepting their dirty habit and certain maxims and observances which they followed in compliance with the rules of their patron saint, lived after the manner of other men, and were therefore considered as laymen; but the denomination was ultimately applied to a great number of other orders and sects, whose followers, female as well as male, pursued a somewhat similar course of life. None of these, however, must be confounded with the true Franciscan Beguines who grew into importance about the same time, but whose origin dates from the 11th century, and whose docrines gave rise to the Lollards. The Beghards were divided into two classes, the *perfect* and the *imperfect*. The first lived on alms, abstained from marriage, and had no fixed dwellings; the second had houses, wives, and possessions, and were engaged in the common avocations of life like other people. Pope Celestin V. was favourably disposed to the Fratricelli, and permitted them to constitute themselves into a separate order. They were submissive to that pope, but they violently opposed his successor, Boniface VIII., and subsequent popes who persecuted their sect. The Fratricelli were accused of great enormities in the beginning of the 14th century, and persecuted by the court of Rome, but they found protection from princes, nobles, and towns, who respected them on account of the austerity of their devotion. In 1317 Pope John XXII. ordered their abolition by a bull, and on their refusal to submit, they were declared heretics. The Fratricelli did not always submit with the meekness of the first Christian martyrs to their persecutors, but frequently opposed force to force, and even put to death some inquisitors in Italy. This sect continued during the 14th century, and spread as far as Bohemia, Silesia, and Poland. The members of it were most severely persecuted in the 15th century, and many of them fled from France to England and Ireland. All the persecutions directed against the sect did not however extinguish it, and some remnants of it existed till the reformation of Luther, whose doctrines they embraced.

FRAUDS, STATUTE OF. [Statute of Frauds.]

FRAUDULENT CONVEYANCE. [Consideration.]

FRAXININ. [Mannite.]

FREE BENCH is the widow's share of her husband's copyhold lands, according to the custom of the particular manor of which the lands are holden. [Copyhold.] As dower is not an incident to copyhold tenure the quantity and duration of the widow's interest are regulated by the custom; it is generally a third for her life, but in some manors it is a fourth part, and sometimes only a portion of the rent. By other customs she takes the whole for her life, and in the manor of Taunton Deane, in Somersetshire, the wife takes the inheritance. In some manors the widow has only a right to Free Bench out of the lands of which her husband died seised; in others, her right attaches upon all the lands held of the manor of which he was seised during the coverture. Frequently her estate is during widowhood only, and sometimes during chaste widowhood. In the manors of East and West Enborne in Berkshire, and Torre in Devonshire, and in some other parts of the West of England, there is the ludicrous custom that where a widow has forfeited her Free Bench for incontinency, if she will come into court riding backwards on a black ram with his tail in her hand, and repeating certain verses more significant than decent, ending with "Therefore pray, Mr. Steward, let me have my land again," the steward is bound to re-admit her to her Free Bench. (Cowel's 'Interp.'; Scriven 'on Copyholds.')

FREE CHURCH OF SCOTLAND, the name adopted by a large body of clergy and laity who seceded from the Church of Scotland in 1843. The history of this secession is as follows. It was part of the policy of the Harley ministry, in Queen Anne's reign, to encourage the Episcopal party and the landed gentry of Scotland, and to depress the Presbyterian. In 1712 they accordingly passed an act (10 Anne, c. 12) restoring to its full vigour the right of lay patronage, which had been virtually abolished in 1690. The church became thenceforward divided into two parties, the supporters of patronage, or the "Moderates," and the anti-patronage men, or, as they were more lately termed, "Non-intrusionists." In 1834 the latter party obtained the majority in the General Assembly, and on the 31st of May of that year the Assembly passed an "Overture and Interim Act on Calls," a measure generally known by the name of the "Veto Act."

To understand the character of this measure, it is necessary to keep in view the method of collating a qualified person to a benefice in Scotland. The licensing of a clergyman, and his ordination and induction to a benefice, are distinct acts. Many clergymen are licensed to preach who never obtain benefices, and in this position they are called "probationers." When a licentiate receives a presentation to a benefice, he presents it, along with an acceptance, to the presbytery within the bounds of which it lies, and they pronounce a sentence sustaining the presentation, and appointing such formalities as the laws of the church sanction, before the presentee is finally ordained and inducted to the benefice. The object of the Veto Act was to make it a law of the church that no presentee was to be held fit to be ordained as minister of a parish unless he were acceptable to the majority of the parishioners. Accordingly, by the Veto Act and other rules for carrying out its principles, presbyteries were directed, when a presentee laid his presentation before them, to appoint him to preach twice in the church, and also to appoint a day for "moderating in a call," or receiving dissents. If a majority of the male heads of families in the parish in communion with the church dissented, the presentee was to be rejected as an unfit person. There was no doubt that it was within the power of the General Assembly to settle what qualifications should be required, in the way of education, character, &c., of every presentee; but the question came to be, whether the church was entitled to require such an external test as the acceptability to the parishioners, and thus virtually counteract an act of parliament under which important civil rights were held.

On the 14th of September, 1834, Lord Kinnoul, patron of the parish of Auchterarder in Perthshire, issued a presentation to that parish in favour of Mr. Young. The presbytery applied the Veto Act to this presentation, and it was found that in a roll of 330 male heads of families, 287 dissented and objected to the presentee's ordination. The presbytery accordingly rejected the presentee. An appeal against these proceedings was taken to the immediately superior ecclesiastical court, the Synod, and thence to the General Assembly, but the acts of the presbytery were confirmed in both these courts. The next step was to call in question the proceedings of these ecclesiastical tribunals in the civil courts. Accordingly an action of declarator was raised in the Court of Session by the patron and the presentee, and on the 5th of March, 1838, the court, by a majority of eight to five, found that the presbytery, in rejecting the presentee on the sole ground that the male heads of families in communion with the church had dissented without assigning reasons, had acted to the hurt and prejudice of the pursuers, illegally, in violation of their duty, and contrary to statute. On the 3rd of May, 1839, this decision was affirmed on appeal in the House of Lords. Mr. Young afterwards raised an action of damages against the presbytery, on the ground of his having been a sufferer by their illegal conduct, and obtained a verdict in his favour. This was called "the Auchterarder case." The presbytery had refused to retrace their steps, and had inducted another person before preventive legal measures could be taken in the matter. But the Lethendy case took a different shape. In 1835 Mr. Clark received a presentation to that parish from the crown, in which the patronage was vested. A majority having dissented, he was rejected by the presbytery. In the mean time the crown, yielding to these proceedings as legal, issued a presentation to another person; and thus the two presentees were able to fight the battle of the legality as a question of patrimonial right. Mr. Clark not only brought an action into court, as had been done in the Auchterarder case, but he likewise applied for an interdict, the counterpart of what is in England called an injunction, and the Court of Session accordingly interdicted the second presentee from presenting himself, and the presbytery from inducting him. The presbytery applied to the General Assembly for instructions, and the Assembly directed them to disregard the interdict of the Court of Session, and to put in force the Veto Act. They therefore proceeded with the induction of the second presentee. On this the majority of the presbytery were cited to appear before the Court of Session, to answer to a complaint for breach of interdict; and on the 14 June, 1839, they were reprimanded at the bar of the court, and informed that a repetition of the offence would be followed by imprisonment.

The celebrated Strathbogie case assumed an aspect considerably different. In June, 1837, Mr. Edwards received a presentation to the parish of Marnoch, which he laid before the presbytery of Strathbogie, the majority of whom were opponents of the Veto Act. A majority of the communicants having vetoed Mr. Edwards, the presbytery, by the direction of the superior church courts, rejected him. A second presentation to a different person was granted by the patron, but Mr. Edwards, as in the case of Lethendy, obtained an interdict against the presbytery taking any steps in favour of the second presentee, and raised an action to have it declared that his own rejection was illegal. In these circumstances the presbytery resolved to postpone their proceedings until the courts of law had given final judgment. Mr. Edwards obtained a decree to the effect that the refusal of the presbytery to take him on trial and induct him was to his hurt and prejudice, illegal, in violation of duty, &c., and enjoining them to take him on trial, and act as if no law of the church such as the Veto Act existed. The presbytery applied to the superior church courts, which directed them still to put the Veto Act in force. Thus, being directed by the courts of law to take a particular step, and by the superior ecclesiastical judicatories to take one in the reverse direction, the presbytery would of course act as their own views of a proper jurisdiction in the matter might direct. The majority being of the moderate party, they decided by a majority that they would obey the courts of law, and they consequently took Mr. Edwards on trial, and inducted him. Then occurred an event from which every one saw that the Church of Scotland must inevitably be split in two. On the 13th December, 1839, the commission of the General Assembly suspended the majority of the presbytery of Strathbogie from their ecclesiastical functions, directed other clergymen to perform their duties, and declared the minority of the presbytery to be entitled to perform the corporate functions of the presbytery. On the 27th May, 1841, this suspension was made perpetual by the General Assembly deposing the members of the majority of the presbytery, and recalling Mr. Edwards's licence as a preacher. In the meantime the court of session interdicted the practical application of these proceedings of the ecclesiastical courts, directing the interdicts against any clergymen of the established church usurping the functions of the majority of the presbytery of Strathbogie, whether individually or collectively. The execution of the sentence of deposition by the General Assembly was also interdicted. Thus the presbytery of Strathbogie was divided into two bodies—the one supported by the superior ecclesiastical courts, the other by the court of session. Both returned representatives to the ensuing General Assembly of 1842, but it was of course only the former who were declared by the Assembly to be duly elected, while the civil court interdicted them from sitting as members of the Assembly.

At the same meeting of the Assembly, in 1842, a vote was carried by 216 to 147, to the effect that patronage ought to be abolished. At the same time the Assembly issued a document called a "claim of right," against the "encroachment of the civil courts," which was transmitted to the government, and answered by the secretary of state for the home department, who left no hope in the minds of the non-intrusion party that their demands would be complied with. Some attempts were made in parliament to carry a measure for legalising the Veto Act, but they may be said scarcely to have had the support of any party, for those who held that the ecclesiastical courts were competent to pass such a measure into a law were not inclined practically to admit their incompetency by soliciting the intervention of parliament. A further step was in progress in the civil courts. They had already protected individuals from the effects of the acts of the church courts by prohibiting these acts from being put in execution. Proceedings were commenced for having these acts of the ecclesiastical courts annulled by the civil tribunals as courts of last resort, to which those who felt themselves injured by the proceedings of any of the constituted judicatories might apply. The court indicated that it would give redress, but these proceedings were suddenly stopped by the event called the "Disruption."

It is the practice for the General Assembly to meet on the third Thursday of May. On its so meeting, on the 18th of May, 1843, before the roll of members was made up, the late Dr. Welsh, professor of church history in the university of Edinburgh, who had been moderator or chairman of the preceding Assembly, read a protest against the constitution of the Assembly, signed by 120 ministers and 73 lay elders. A copy of this protest being left with the clerk of the Assembly, those who had signed it, and their adherents, left the Assembly in a body, and constituted in another place "the General Assembly of the Free Church of Scotland," choosing Dr. Chalmers as their moderator. This step is presumed to have been taken in consequence of the tactics laid down in the deliberations of a considerable body of the non-intrusion party who had met at Edinburgh on the 17th of the previous November, and conducted its proceedings with closed doors, being called a "convention of ministers and elders of the Church of Scotland." On the 23rd of May an "act of separation and deed of demission" was adopted by the General Assembly of the free church, and signed not only by those clergymen who were members of the Assembly, but by others who participated in their views. Thus no difficulties were put in the way of a complete separation of these persons from the benefits and burdens of the establishment. Whatever previous differences of opinion existed, and whatever objections there were to a body such as the General Assembly of the Church of Scotland, entitled to legislate and adjudicate for its own interests and according to its own feelings, being exempt from the control of the courts of law, the sacrifice of emolument and station thus made elicited general respect and sympathy, and was creditable to the sincerity of those who made it. The free church are now in possession of large sums supplied by voluntary contributions, they have established ministers in nearly every parish in Scotland, have founded a college, and are widely extending their operations.

But a fresh cause of dispute has arisen. The General Assembly of the Free Church claims the right of deciding on the fitness and orthodoxy of the ministers of the churches in connection with it. The minister of Cardross having been suspended from the duties of his office for a definite period, and for assigned causes, by the Presbytery of his district, appealed from it to the General Assembly, which increased the penalty by ordering his total removal. From this sentence the minister appealed to the Scottish law-courts. The General Assembly demurred to the civil jurisdiction, on the ground that the minister had subscribed to a declaration that he would conform to the regulations of the General Assembly. The court, however, held that this could only apply to the ecclesiastical duties, and not to his civil rights, which had been injured by the General Assembly going beyond the question which had been submitted to them, namely, whether his suspension should be removed or not. No ultimate decision has yet been arrived at (January, 1860).

FREEHOLD. An estate of freehold is defined by Britton to be "the possession of the soil by a freeman;" and by Sir William Blackstone, as "such an estate in lands as is conveyed by livery of seisin, or in tenements of an incorporeal nature by what is equivalent thereto." Neither of these definitions is sufficiently precise; both are the consequence of the tenure, not the tenure itself.

A freehold, "liberum tenementum," was simply an estate for life in tail or in fee, held by a freeman independently of the will of the feudal lord, and the term was used in contradistinction to the interest of terms for years, and lands in villenage or copyhold which might be determined by the lord at pleasure. The older law writers distinguished freeholds as of two kinds, in deed and in law; the first being the actual possession of lands for an estate of freehold; and the other, the right to such lands before actual possession taken. Blackstone divides them also into freehold estates of inheritance, and freehold estates not of inheritance. Neither of these divisions is of any real importance. In the absence of a better definition, a freehold may be described to be an estate in lands or tenements in fee simple, in tail, for the life of the holder, or for the life of another person, in dower or by the courtesy. Some offices also, held for life or in fee, are said to be of freehold tenure.

FREE-SCHOOL. [SCHOOL.]

FREE-TRADE. [TRADE.]

FREE WILL. The perplexity in which this question has been involved is perhaps mainly owing to carelessness in the use of terms; and yet, however carefully we may select and use our terms in discussing this question, it has always been found very difficult to state it clearly. Hartley puts the question thus:—He "embraces the opinion of the mechanism or necessity of human actions, in opposition to what is generally termed free-will;" and he says, "by the mechanism of human actions, I mean that each action results from the previous circumstances of the body and mind, in the same manner, and with the same certainty, as other effects do from their mechanical causes; so that a person cannot do indifferently either of the actions *A* and its contrary *a*, while the previous circumstances are the same; but is under an absolute necessity of doing one of them and that only. Agreeably to this, I suppose that by free-will is meant a power of doing either the action *A* or its contrary, while the previous circumstances remain the same. If by free-will be meant a power of beginning motion, this will come to the same thing; since according to the opinion of mechanism, as here explained, man has no such power; but every action or bodily motion arises from previous circumstances, or bodily motions, already existing in the brain; that is, from vibrations, which are either the immediate effect of impressions then made, or the remote compound effect of former impressions, or both. But if by free-will be meant anything different from these two definitions of it, it may not perhaps be inconsistent with the mechanism of the mind here laid down. Thus, if free-will be defined the power of doing what a person desires or wills to do,—of deliberating, suspending, choosing, &c.,—or of resisting the motives of sensuality, ambition, resentment, &c.,—free-will, under certain limitations, is not only consistent with the doctrine of mechanism, but even flows from it; since it appears from the foregoing theory, that voluntary and semi-voluntary powers of calling up ideas, of exciting and restraining affections, and of performing and suspending actions, arise from the mechanism of our natures. This may be called free-will in the popular and practical sense, in contradistinction to that which is opposed to mechanism, and which may be called free-will in the philosophical sense." This passage is not selected as being a peculiarly successful statement of the question, but simply because it shows with sufficient accuracy what the matter under consideration is, and that independently of the author's theory of vibrations.

Necessity, according to the common definition is that quality of a thing by which it cannot but be, or whereby it cannot be otherwise. When, in a proposition which affirms any thing to be true, there is a fixed invariable connection between the subject and the predicate, then that thing is understood to be necessary. Necessity is opposed to chance, accident, contingency, and to whatever involves the idea of uncertainty and of possible variation. It is usually distinguished into logical, physical, and moral necessity. Logical necessity consists in the circumstance that the conception of something being different from what it is, implies a contradiction or absurdity. In this sense it is necessary that two and two should be four, that converging lines, if produced far enough, should meet: thus also the eternal existence of being generally is necessary, as are innumerable other truths. Physical necessity has its origin in the established order and laws of the material universe. The necessity, in this case, differs from that formerly specified, in that it is only conditional, is a necessity of consequence. Everything that takes place in the natural world happens by virtue of certain laws: these laws are known by experience to operate regularly and uniformly; and the results of their operation are hence, with reference to them, said to be necessary. When we ascribe anything to chance, we merely state our ignorance of the law or laws to which its existence is to be referred. Physical necessity is founded on the relation of cause and effect. By tracing back this connection, we arrive at the knowledge of a great first cause, that is God, who is the only Being existing independently and by an absolute necessity. His infinity and other attributes are necessary; and it is evident that the purposes and acts of such a Being must also be necessary, being determined by that necessity by which he is what he is. He must always resolve and act with the most perfect wisdom, justice, and goodness. To affirm the contrary would be to affirm that he is different from what he is. Moral necessity has reference to the volitions and actions of rational agents, and is intended to express the connection between these volitions and actions, and certain moral causes, as inclinations, desires, or motives generally. Whether there be any connection which, strictly speaking, may be termed necessary, between such motives, and the resolutions of the human will, and the consequent actions, or whether, independent of them, the will has a self-determining power, is an inquiry which has largely engaged the attention of both philosophers and theologians. It is one of great interest, and which has an important bearing, on whatever relates to man as the subject of a moral government. [WILL.]

The doctrine of a universal necessity, or fatalism, was maintained by many of the ancient philosophers; and formed the characteristic tenet of the Stoical school. According to it, necessity was to be considered as an inevitable and all comprehending principle, to which gods as well as men were subject. Everything was conceived to exist in a necessary series of causes and effects—the whole constitution of nature—the modes and circumstances of all things without exception—being irresistibly and unchangeably determined. Hence the language of Seneca, the elegant expounder of the opinions of this sect, in his treatise 'On Providence:'—"The same necessity binds both gods and men—Divine as well as human affairs proceed onward in an irresistible stream—one cause depends upon another—effects are produced in an endless series—nothing is the offspring of chance." Democritus held opinions closely resembling the Stoical doctrine of fate; as also Heraclitus, the founder of the sect that went by his name. In modern times, the doctrine of necessity, especially in regard to the human will, has been defended by Hobbes, Leibnitz, Priestley, Hume, Kaimes, Hartley, and many others.

The universal language and practice of mankind imply a belief in a kind of free-will. To deliberate, to choose, to determine, and to act in pursuance of such determination, are expressions in every man's mouth, and things within every man's ordinary experience, both of himself and others. Every man also supposes that another will choose and determine pretty much in the same way that he himself would under the same external circumstances; that is, each man believes that every other man will be governed by motives, or will act according to motives, in the main pretty much as he would himself. When men act differently under the same external circumstances, the cause of the difference in conduct is not referred to the circumstances, in which it is here supposed that there is no difference, but to some difference in the persons. We believe, therefore, that circumstances move men to act, but that we have at least a certain power of weighing these various motives and giving the preponderance to one or another, and that different men possess and exercise this power in different degrees. This may be called, in a sense, a free exercise of the will, and every man, at least who is of sound mind, believes that he has this power, and is supposed by others to have it.

The belief that man possesses this power is the foundation of laws which forbid acts under certain penalties. All legislators have believed that the knowledge that a certain punishment will follow a certain act if detected, operates in some degree on those who are disposed to do the forbidden act; that the persons who are by any motives led towards such act may, and as a general rule will, deliberate on the penalty attached to the act before they do it, and will often be prevented from doing it by a comparison of the advantage which they expect to derive from the act, with the certain penalty attached to it. Many persons do not violate the law because they have been brought up in habits of uniform obedience to it, and therefore the penalties of the law have little or no effect upon their conduct; but it will hardly be disputed that the fear of punishment has some effect on many men, and is a motive which, operating on the mind and operated upon by the mind, produces self-restraint. The enactment of penal laws supposes a power in men to determine how they will act; or, in other words, it supposes at least that motives can be presented to men which shall in some way and in some degree determine their conduct.

That men, then, do act under the influence of motives, and that they have also the power of weighing motives, is universally admitted, and for all practical purposes it is immaterial to inquire any further. A man subjects himself to a certain discipline, he educates his children in a certain method, and legislators forbid men to do a variety of acts,—all acting under the belief that the discipline, the education, and the rules of law are so many motives, which, by constantly operating on the mind, will produce on the whole a certain line of conduct in those who are the objects of them.

But it has been already said, that the external circumstances or the motives being the same, two persons will often act differently under them. As the external motives are by the supposition the same, there is some difference in the persons which causes the difference of conduct. Under the same external circumstances, one man will violate the law, and another will not; one will steal and rob, and commit murder, and another will not. It is generally said that the transgressor of the law is punished on the supposition that his act is voluntary; that he could, if he chose, have acted differently. Practically, he who executes the law will not trouble himself with the question whether a particular individual could have acted differently under the circumstances: if it is shown that such a person possessed the ordinary understanding of mankind, he will see no reason for remitting the punishment; because he believes that in most cases, if not in all, the penalty attached to a particular act will operate to deter people from doing it. The question of an absolute free-will, then, does not concern a legislator. It is enough for him to present the proper motives for acting or not acting in certain ways, if he believes that such motives will on the whole produce the conduct which he requires. Nor does the question of absolute free-will concern any other person who has to direct or operate upon others. If he believes that he can place such circumstances around persons, or present to them such motives, as will cause a determinate course of action, it is unimportant whether he believes that the course of action is necessarily determined by these circumstances, or by these concurring with other circumstances, or that the persons who are under their influence do in some way or other choose and determine to act as he wishes them to act.

But if we examine more closely any particular act of a man's life, suppose it to be an act which has about it all the marks of slow deliberation, in what sense can we say that this is an act of absolute free-will? The ordinary language of mankind assumes the existence of choice,—deliberation,—and yet it does not permit us to maintain that every act is an act of absolute free-will. If it is a virtuous act, we do not barely ascribe it to a man's careful consideration of all the motives which at the time operated on him; we speak of his habits, his education, his character, as the things which would ensure his acting on a given occasion in a determinate way, or, if we so choose to express it, as securing that exercise of the will which is called a proper exercise. And we make the like remarks of a man who has deliberately done a bad act. In both cases we do not attribute the whole conduct of the man, nor yet the greater part of it, to his then determination. We refer to antecedent circumstances as co-operating to this determination. This is the language of all mankind; and the language of all mankind, when rightly analysed, is the true exponent of universal opinion. Confused and perplexed as it often is, it contains within it implicitly the elements of all philosophy. Now, when we once refer to antecedent circumstances as affecting our determination under the motives that are presented on any one occasion, we give up the theory of an absolute free-will, for we make every act of will depend, in some degree at least, on something prior; and that something, again, must by the like reasoning depend on something prior to it; and thus we have an infinite chain of events, and consequently we find ourselves engaged in an inquiry which is beyond the reach of our capacity. Thus, if, as Hartley says, "by free-will be meant a power of beginning motion," no person can, consistently with his own ordinary language and that of others, maintain this proposition; if he does, he will contradict himself almost as often as he speaks.

Human actions, then, are, in some degree at least, subject to the same general laws to which other events are subject. Every human action has its antecedents, on which it in some degree depends; but whether every human action is as necessary, in the sense in which Hume explains the term necessary, as the other phenomena which we see, is precisely the matter in dispute. (Hume, Essays, 'Of Liberty and Necessity.')

When it is said that every event and every human action has its antecedent on which it depends, it must not be understood that it is meant, here at least, to maintain anything else than this. Such antecedents are events which, according to our experience, precede the given event uniformly, or at least with sufficient uniformity to generate in our minds the notion of a certain order or continuity; for though any given antecedent event is called the cause of any event which uniformly follows it in our ordinary mode of speech, we here mean to express nothing more than the fact of this uniform sequence. The utmost that we can say is, that the antecedent event is, according to the constitution of the universe as known to us, a necessary condition to the subsequent event. Neither heat, nor moisture, nor anything else that we can name, is the cause or a cause of a seed vegetating and producing a plant like that from which it came. Heat and other things are conditions of vegetation as known to us. The efficient cause can only be one, which must be perpetual, and beyond which we seek for no other. This efficient cause is no law of nature, a term which is incapable of all strict analysis. It is the will of God to those who admit the existence and omnipotence of the Deity. To those who do not, if there be such, it is something which has never yet been explained.

Now as all human actions have their antecedents, without which, according to our experience, they could not be, it follows that there are certain antecedents of every action which are its conditions, without which such action would never be. This cannot be denied. It is the ordinary language of mankind expressed in a different form. But still it is perfectly consistent with this to speak of man exercising his will, that is, operating on the motives which are presented to him. On any given occasion man is subjected to various momenta, and it may be admitted that each man will be directed by that which to him at the time is the strongest. But if a power of estimating different motives be admitted to exist in the mind, and to exist in different men in different degrees, the strength of the motive is not its own strength acting on the passive mind; it is the activity of the mind which according to its power comprehends the motive completely or incompletely.

If the analogy is sound between human actions and other phenomena, and if in other phenomena the antecedents or conditions are not causes, so neither are the antecedents or conditions of human actions to be viewed as their causes. Man is constantly subjected to various momenta, motives, or circumstances, as they are often called, without which he would not act as he does act. These momenta are traced back by an infinite series to the first cause of all, just as in the bare physical phenomena, if we trace them far enough, we must ascend to a first cause. If the analogy then is complete between man's acts and other phenomena, the operation of all these complicated conditions in some way determines the acts of man; but how it determines them we cannot tell. There is no person who maintains the doctrine of absolute free-will who will contend that man can set his will in opposition to that of God. It is possible to conceive that God does will to let man have free action within certain limits, but not further; and all our forms of speech do either expressly or by implication admit that our will is free to a certain extent, which we cannot exactly define, but that it is not absolutely free. It may be objected that to deny an absolute free-will destroys the distinction between actions; that it represents the Deity as the cause of vice and misery. But even if it should be so, that will not prove a thing to be false which is established by the sound exercise of our understanding. No such consequence however does follow. To God we attribute the origin of everything; and consistently with this we must say that he permits vice and misery to exist in the world. It is a consequence of man's nature as he is constituted, and under the circumstances in which he is placed, that he has acted and does act in such a way as to cause misery to himself and others.

It must therefore be assumed that God has, for reasons unknown to us, so constituted man that he does not always act in the way that is most consistent with his own happiness and the happiness of others. The vicious conduct of many men in life is an object of disapprobation to others, and in all societies that conduct which is injurious to the existence of such societies is visited with penalties. Thus a vast majority of mankind see that certain acts are injurious to the general happiness, and it is one main object of society to prevent such acts. As God permits society to exist, we may assume that he wills it to exist, and that he wills generally the means by which society attempts to secure its own existence. It is a consequence of this that he disapproves of the conduct of those whose acts endanger the existence of society. We cannot say that he does not will it: it exists, and therefore is consistent with his general will. We are compelled therefore to apply to him by analogy such terms as are applicable only to our own limited capacities: and we say that he wills generally that all things shall be as they are, but that he disapproves of some. That he permits man so much liberty of action as to render it necessary for society to be vigilant against the evil doers who would disturb its repose, is no more an imputation upon his goodness than that he permits fire, tempest, and war and pestilence and famine to thin the numbers of mankind. So far as concerns those who suffer, it is the same thing whether they suffer from the hand of man, or from causes over which he has no control. It is consistent with all experience to say that the Deity has willed that man shall suffer pain both through the agency of matter and through the agency of his fellow-men. Now if we shall assume that God only wills our happiness in the sense in which many persons understand it—which would, according to their notions, exclude all pain and suffering—whatever misery happens through man's misconduct must be against his general will, and can only result from man having an absolute free-will, and sometimes exercising it in a way different from the Deity's wishes. There is no evading this difficulty. An absolute free-will in man or in any other being is inconsistent with the omnipotence of the Deity, and it is, as already shown, contradicted by all our observation of the mode in which man is operated upon by motives and circumstances. But there is nothing which prevents us from attributing to man, as we do in our daily expressions, a power of determining his acts, under given circumstances, in one direction rather than in another, and in a wrong in preference to a right direction. And it is further admitted by the universal language of mankind, that the same man who acted wrong under one set of motives, might and would have acted right if he had been influenced by other motives; and these motives to right action, it is also admitted, may be and frequently are external circumstances over which he has no control. It is true that a man may so discipline himself, that, in any given circumstances which may arise, he may have motives at his command which shall enable him to act in the right direction, a power which Hartley speaks of in the passage at the head of this article. But if some men can do this, all cannot; and even in the case of him who can do it, we may always trace the origin of this power to some external circumstances over which he had no control. Man's will then is circumscribed by the constitution of things, of which he is a part. He is placed in circumstances in which he is operated upon by various motives to action. If it is said that he must be determined absolutely by that which is the most powerful, this is only another mode of saying that of various forces tending to make him move, the strongest will carry him in its own direction. But in truth the words force, motive, and others of a like kind, are apt to lead us to false analogies: and these terms require explanation.

Every man believes at the time when he acts with deliberation that he has a capacity for exercising a free-will. But he also knows that circumstances may prevent deliberation. Thus it is a common case for a man to allege that if he had not been alarmed or hurried, he would have acted differently; or in other words, he would have been enabled to deliberate and decide better. No man considers it to be a case where the will is properly concerned when his action is thus impeded. And there are numerous like cases in life in which in fact there is no choice or deliberation, and consequently no real exercise of the will. The power, then, whatever it may be, to deliberate and act, is often suspended or not exercised. In most cases we act from habit in the general course of life; in other cases from impulse; and when we act from impulse, there is no deliberation or determinate will. It appears then that our will is not always exercised when we act, but that when it is exercised we are conscious of a capacity to weigh deliberately the various motives or grounds of action as presented by our own mental activity. Now if we say that the strongest motive thus presented must prevail and determine to action, we may, as above observed, be misled by a false analogy. The motive may be called a moving power; and if so, it must have its effect: but to deny the mind all power in itself to resist the motive, is the same thing as to consider it an inert mass operated upon solely by an external force. It is the same thing as to make the mind of man a recipient of sensuous phenomena without any power to operate on them. The systems of philosophy which view the mind as such a recipient will be consistent in making it yield to the strongest motive without an effort of its own. Those systems which assign to the mind a power of operating on impressions may consistently admit a power of determining which of them it will obey.

God the creator of the universe is omniscient. To him time past, present, and future, is one. We conceive him as knowing all things, willing all things, directing all things. But our acts of free-will then, it may be urged, are God's will, and therefore not man's. Therefore free-will in man in any sense contradicts our notion of God's power. To this we answer, that man's power to will is here considered as a fact of which our daily experience convinces us; and further, that the existence of this power is a legitimate deduction from the nature of man's mind, which is here supposed to have an activity independent of all sensuous impressions. It is admitted that if our actions are viewed in reference to the power of God, as we conceive it, we cannot reconcile our notion of the freedom of our actions with our notion of the power of God. But there is no contradiction here. Contradiction implies that the things between which it arises are equally within the cognisance of our understanding. It is no contradiction to say that God wills all men's acts, and that man wills his own. Both things may be true, though we cannot comprehend how it is so.

FREEDMAN. [Slave.]

FREEMAN. [Municipal Corporations.]

FREESTONE. A term applied by practical masons to those descriptions of building stones which are able to be worked with the ordinary mallet and chisel, in contradistinction to those which are worked by the pick, or which it is necessary to stun. The various descriptions of oolites, sandstones, limestones, and the softer kinds of grits, are classed as *freestones*, and they may all be sawn, either by the plate or by the toothed saw; the granites, the millstone grits, the burrs, and the lavas or basalts, are not included in this class: nor are the slate rocks, though they are capable of being sawn by the plate saw. In fact the term freestone is only applied to those materials which are susceptible of easy conversion to the ordinary purposes of building, and the distinctly marked cleavage of the slate rocks renders this operation almost impossible in their cases.

FREEZING is the solidification of fluid bodies by the abstraction of the heat necessary to their fluid form. It occurs by the effect of natural cold in many liquids; and most of them may be frozen by an artificial reduction of temperature. It is to be observed, that what are termed the *freezing points* vary greatly in different fluids, and their remaining such at different temperatures depends upon the different degrees of power with which they retain the heat necessary to fluidity. Liquids may be considered as solids in combination with heat, which exists in them in a latent state, and which they give out as sensible heat when they return to the solid form.

In passing into the solid state, certain liquids undergo a sudden and often considerable change of volume, which may either be an enlargement or a diminution. For example, when mercury is cooled to —39° Fahr., a great and sudden contraction takes place; so much so, that when observed in a thermometer, it falls through a considerable number of degrees, and the whole of it may retire into the bulb. The reverse of this takes place in the case of water. In passing from 38·8° to 32°, its freezing point, it undergoes a regular expansion; and in passing into the solid state it undergoes a further expansion, amounting to one-seventh of its bulk. And so irresistible is this expansion, that rocks are rent asunder by the freezing of water in their crevices; vessels and pipes containing water are burst; and it was calculated, in the case of a strong brass globe, filled with water and closed by a screw, and burst by the freezing of the water within it, that the force necessary to produce this effect amounted to not less than 28,000 lbs. When liquid phosphorus is gradually cooled it regularly contracts; and, passing into the solid state at about 100°, it undergoes a sudden and considerable contraction. The same observation applies generally to oils in the process of freezing, and it has been remarked that, in general, bodies which do not crystallise in freezing undergo a sudden contraction, while those which do so crystallise undergo a sudden expansion. Sulphuric acid, however, in becoming solid, or passing from the solid into the liquid state, does not appear to suffer any change in volume. Cast iron, bismuth, and antimony expand in solidifying; the other metals, however, contract in doing so.

What are called *freezing mixtures* are such as produce cold by and during the liquefaction of their solid ingredient, and the consequent absorption of the heat on which its solid form depended. Such mixtures reduce the temperature of substances immersed in them on the principle of the transfer of heat, which always takes place from hotter to colder bodies when exposed to each other.

The process used by confectioners for producing cold is by the mixture of ice and common salt, which, both liquefying, absorb so much heat, or in other words produce as much cold as will reduce the thermometer from the usual temperature to the zero of Fahrenheit's scale, or even rather below it. If, however, freshly fallen snow be used instead of ice, then the fluidity is more suddenly produced and the cold is more intense.

In freezing mixtures, the substances combined have such an affinity for each other that when intimately blended they combine chemically, and in doing so liquefy. The operation should be so arranged that no heat be furnished either by the vessel in which the liquefaction takes place, or from any external source. Under such circumstances, the heat absorbed during the liquefaction must be furnished by the materials of the freezing mixture (in which case the reduction of temperature will be proportional to the quantity of heat rendered latent), or by the body which it is intended artificially to cool or to freeze.

The reader will find in works on chemistry many recipes for freezing mixtures. One or two examples will suffice here. With equal weights of fresh snow (or pounded ice) and common salt a temperature of —4° Fahr. can be maintained for many hours. A mixture of three parts crystallised chloride of calcium and two parts of snow will produce a depression of temperature sufficient to freeze mercury. If the vessel in which the materials are to be mixed and the chloride be cooled to 32°, a temperature of —50° can be produced. The most powerful freezing mixture is formed by dissolving solid carbonic acid or solid nitrous oxide in sulphuric ether. In this way temperatures of —120° to —146° have been obtained, at which alcohol passed from the consistency of oil to that of melting wax. For more moderate temperatures, certain salts easily procurable may be used. Thus, 4 ozs. of nitre and 4 ozs. of sal ammoniac, both in fine powder, mixed with 8 ozs. of water, will reduce the thermometer from 50° to 10°. Equal parts of water, of powdered crystallised nitrate of ammonia, and of powdered crystallised carbonate of soda, will lower the temperature from 50° to —7°.

FREEZING APPARATUS. The first apparatus of this kind was an air-pump contrived by Sir John Leslie for the purpose of freezing liquids in vacuo.

It is well known that liquids evaporate more readily when the atmosphere is removed from their surfaces than when they are subject to its pressure; the caloric producing the evaporation being that which exists in the liquid itself, and that which, in consequence of the disturbance of the equilibrium, enters the liquid from the neighbouring bodies: hence, if there be a quantity of sulphuric ether in a vessel under the receiver of an air-pump, and in it there be placed a vessel or tube containing a small quantity of water, on exhausting the receiver the ether will rapidly evaporate, and, the operation of exhausting being continued, the vapour will be carried off as fast as it is formed. The caloric in the water is withdrawn at the same time, and at length the water is converted into ice.

In order to produce the congelation of water by a rapid evaporation from its own surface under the exhausted receiver of an air-pump, Leslie introduced into the receiver a shallow vessel containing highly concentrated sulphuric acid, above which was placed the vessel containing the water. The air being extracted as quickly as possible, the vapour—which, in consequence of the removal of the pressure, escaped continually from the water, even at the medium temperature of the atmosphere—was, by the strong attraction of the acid for it, absorbed as fast as it rose; and in two or three minutes the quantity withdrawn from the water was sufficient to allow a congelation of the water to take place. Instead of sulphuric acid, any substance which (as dry potash, muriate of lime, or calcined powder of basalt) has a strong attraction for humidity may be used; but the first, if highly concentrated, is the most efficacious.

The air-pump employed for the purpose by Leslie was constructed in the usual manner, but of large dimensions, in order to obtain ice in considerable quantities, and the receiver was a segment less than a hemisphere, that the air contained in it might be extracted as speedily as possible. The sulphuric acid or absorbent earth was contained in a shallow vessel of glass, nearly equal in diameter to the base of the receiver; and from the centre of the vessel rose a hollow cylinder, on the top of which, above the acid or earth, rested the cup of glass, or rather of unglazed earthenware, which contained the water to be frozen. Machines of this kind have been varied in different ways, the last and most successful of which produced great blocks of ice by the evaporation of ether, and the process of welding slabs of ice as fast as they were formed. The ether was conducted into a separate chamber and condensed, so that it could be used over and over again with little or no loss. This apparatus was patented by Mr. Harrison, "for producing cold by the evaporation of volatile liquids in vacuo, the condensation of their vapours by pressure, and the continued re-evaporation and re-condensation of the same materials." A detailed account of this apparatus with diagrams, is given in the 'Pharmaceutical Journal,' xvi, 477, but we may state briefly that the apparatus consists first of an air-tight metallic vessel, from which air is removed by a pump, and in which ether is kept constantly evaporating; secondly, of an air-tight metallic vessel, into which the ether vapour as it is removed from the former vessel is condensed under pressure; thirdly, of a pump, by which the vapour of the evaporating ether is withdrawn from the first vessel and forced into the second, where, as the pressure increases, it assumes the liquid state ready to be again evaporated. Thus the process is continuous, and there is no appreciable loss. The first and second vessels are surrounded by water, and the cold caused by the rapid evaporation of the ether in the former vessel causes the water surrounding that vessel to freeze, while there is, of course, a corresponding elevation of temperature in the water which surrounds the other vessel where condensation takes place. The only expense is said to be for motive power, which is supplied by a steam-engine of 10-horse power, and it is stated that 1 ton of coal economically applied, is equal to the production of 4 tons of ice. The apparatus was exhibited in London in the summer of 1858, and is now, we believe, in Australia.

Leslie, by means of the like apparatus, succeeded in freezing mercury by the absorption of caloric from a coating of ice in which the bulb of a thermometer was enveloped. In the performance of this experiment, the thermometer was suspended from a wire which, passing through a collar of leathers at the top of the receiver, could be raised and lowered at pleasure. A cup of water was placed above the vessel containing the sulphuric acid; and the bulb of the thermometer, after being lowered into the cup, was drawn up and suffered to lose caloric by the evaporation of the adhering water, in the exhausted receiver: this process being repeated several times, the bulb was at length covered with a film of ice. The cup of water was then removed, and the thermometer, having its bulb thus covered, was allowed to remain suspended about half an hour above the sulphuric acid, the exhaustion of the air being made as complete as possible, so that the column of mercury in the barometer-gauge was within 1-20th inch as high as in a barometer which indicated the density of the external air. On re-admitting the air, and removing the receiver, a portion of the mercury in the ball of the thermometer was found to be frozen. In another experiment, the mercury was inclosed in a mass of ice worked by heat into the form of a cup, and suspended above the sulphuric acid in a small net made of wire. The mercury was introduced into the cup of ice, and on it was poured a small quantity of water. On exhausting the receiver, the water was immediately frozen, so that the mercury was then completely enveloped with ice; and in a few minutes, on removing the receiver, the mercury was found to be wholly frozen. [EVAPORATION.]

FREEZING AND MELTING POINTS, a term applied to the temperatures at which certain liquids become solid, or certain solids become liquid. Thus, mercury becomes solid at —39° Fahr., oil of vitriol at —30°, bromine at —4°, water at 32°, phosphorus at 111·5°, and so on. These points are also entered as *fusing points*. [FUSION.] Thus we say that yellow wax, on the reduction of the temperature, becomes solid, and also, on being heated, begins to fuse at 143·6°, iodine at 224·6°, sulphur at 239°, tin at 451°, nitrate of soda at 591°, lead at 620°, nitrate of potash at 642°, zinc at 773°, antimony at about 900°, silver at 1773°, copper at 1996°, gold at 2016°, cast iron at 2786°, and wrought iron at about 3280°.

Although there is nothing essentially different in the passage of water and cast iron from the fluid to the solid state, yet for temperatures above that at which water becomes solid, the term *freezing* is not usually applied, but rather the *point of solidification*, or, as before stated, the *fusing point*. It is remarkable that the freezing point of water, a liquid which expands in freezing, becomes lowered to a minute but measurable extent by exposing the water to strong pressure. According to Professor Thomson, of Glasgow, a pressure of 8·1 atmospheres lowers the freezing point 0·106° Fahr., and a pressure of 16·8 atmospheres 0·232°; whereas, in bodies which contract in becoming solid, the melting point is found to be raised by pressure. Thus, spermaceti, which under atmospheric pressure became solid at 117·9°, under a pressure of 150 atmospheres solidified at 123·6°.

FREEZING MIXTURES. When certain substances are brought into intimate contact, a more or less considerable degree of cold is produced. Such mixtures are denominated freezing mixtures.

The principle on which the action of freezing mixtures depends is the following. When solids assume the liquid condition a large amount of heat is always absorbed or rendered *latent;* and when liquids assume the gaseous condition a large quantity of heat is also thus taken up. For example, when a piece of ice having a temperature of 32° Fahr. is plunged into its own weight of water at 174° Fahr., the ice immediately begins to liquefy, but during that liquefaction enough heat is absorbed by it to bring down the temperature of the hot water to that of the ice itself; 142 degrees of heat having thus disappeared, the thermometer taking no note of it. Again, the same body, water, when exposed in a vacuum under favourable circumstances, takes up so much heat in assuming the gaseous condition, that portions of it are converted into ice; the one part that boils away robbing the remainder of the heat that kept it in the liquid state.

From the fact that water in passing from the solid to the liquid state has the property of taking up, or rendering latent, a greater amount of heat than any other substance, it follows that solid water must be a powerful agent in producing artificial cold, and this is in practice found to be the case. It is employed in the form of powdered ice or snow, or sometimes combined with certain salts, constituting their so-called water of crystallisation.

Before giving the formulæ for some freezing mixtures, it will be as well to premise that, as a general rule, the substances composing them should be finely powdered, rapidly mixed, as large a quantity as wanted made at one operation, and the whole placed in vessels possessing the smallest possible amount of conducting power. The greatest amount of cold obtainable with the substances used, is only produced when they themselves, as well as the vessels used in the operation, are all previously cooled by freezing mixtures.

In addition to the freezing mixtures given under FREEZING, the following may be mentioned as useful frigorific agents :—

Mixtures.	Parts.	Thermometer sinks	Degree of cold produced.
Nitrate of ammonia	1	From +50° to +4°	= 46°
Water	1		
Chloride of ammonium	1	From +50° to +23°	= 27°
Water	4		
Sulphate of soda	3	From +50° to −30°	= 80°
Dilute nitric acid	2		
Sulphate of soda	6	From +50° to −14°	= 64°
Nitrate of ammonia	5		
Dilute nitric acid	4		
Phosphate of soda	9	From +50° to −12°	= 62°
Dilute nitric acid	4		
Sulphate of soda	8	From +50° to −3°	= 53°
Hydrochloric acid	5		
Snow	12	From +32°=57°	to −25°
Common salt	5		
Nitrate of ammonia	5		
Snow	8	From +32° to −27°	= 59°
Hydrochloric acid	5		
Snow	4	From +32° to −40°	= 72°
Chloride of calcium	5		
Snow	1	From −40° to −73°	= 33°
Chloride of calcium (crystals)	3		

The rapid evaporation of ether *in vacuo* has recently been rendered available for the manufacture of ice upon a large scale, and as the ether is evaporated and condensed again by steam power, it may be truly said of the process that it produces ice by the combustion of coal. It is found that the combustion of one ton of coal yields about five tons of ice.

For common experimental purposes the most convenient freezing mixtures are the sulphate of soda and hydrochloric acid, or salt and powdered ice.

FREIGHT. The charge made for the carriage of merchandise in a ship, and the amount of which is generally specified in the bill of lading. [BILL OF LADING.] It frequently happens that the whole ship is hired by a merchant for the performance of the voyage, and in this case a certain amount of freight is paid without reference to the quantity of goods actually put on board, which may be sufficient to fill the ship, or any quantity short of the same. In such cases the mode of payment is part of the matter of agreement between the ship-owner and the merchant, and the instrument by which this and other stipulations are set forth is called a charter-party. Where no such instrument exists, and the shipper of goods does not stipulate for the right of using the entire portion of the ship appropriated to the reception of her cargo, the amount of the freight, as well as the mode of payment, is usually inserted in the bill of lading. Where this is not done, the freight is by law considered due on the part of the merchant on the delivery of the goods, and the owner or master of the ship may, if so minded, demand payment of the same, package by package, as the same are delivered. In almost all branches of trade, however, some custom in this respect has arisen which is ordinarily pursued, and the legal rights of the ship-owner are not enforced in this respect. In London, where the greater part of the merchandise brought from foreign countries is delivered into the custody of one or other of the incorporated dock companies, a custom has arisen of arresting the goods in their hands, so that they cannot pass away from the original importer until the ship-owner, or some person acting on his behalf, has signified in writing that the freight has been paid. If goods are damaged on board the ship, through the carelessness or wilful neglect of those in whose charge she and her cargo are placed, so that the owner of the ship is held to be liable for the amount of the damage, this cannot, but with the consent of the owner or master, be set off against the amount of the freight, which must under all circumstances be paid, and the merchant must afterwards substantiate his claim to compensation for the amount of the damage.

FRENCH CHALK. [COLOURING MATTERS.]

FRESCO PAINTING. A painting is said to be *a fresco*, or painted in fresco (*sul fresco intonaco*, upon the fresh coat), when it is executed in water-colours upon a freshly plastered wall, while the plaster is still wet; or upon wet plaster spread upon a wooden frame or any other object. Fresco is the most noble and imposing of all methods of painting. It does not admit of the softness, delicacy, or finish of execution, or the richness and depth of colour, of oil-painting; but the very want of the inferior beauties compels the painter to rely upon the highest intellectual conception, composition, drawing, and expression, united with a largeness of style and freedom of handling, which can only result from great technical knowledge. It is therefore only in the hands of the great painter that fresco is likely to be really successful.

Colouring in fresco was practised by the ancients, though it has not yet been shown that they *painted frescoes*. Some of the walls at Pompeii are coloured in fresco, but their decorations are executed in some species of tempera upon the fresco coloured wall. This is evident, because in many places the paintings have cracked off, and exposed the original colouring of the ground in perfect freshness, and the same as the rest of the wall where no decorations are painted. The Roman term equivalent to fresco is *udo tectorio*, and it is used by Pliny ('Hist. Nat.' xxxv. 31), who gives directions as to what colours it is safe or unsafe to apply in this manner. Vitruvius (vii. 3) explains the mode of preparing the walls for this species of colouring, and describes a method of varnishing them when coloured, to preserve them. They first covered the wall with a layer of ordinary plaster, over which, when dry, they placed successively three other layers, of a finer quality, mixed with sand; above these they placed again three layers or coats, of a composition of chalk and marble-dust, the upper coats in this case being each added before the under one was dry, and successively of finer qualities. By this elaborate process the plaster formed a solid mass, as it were, of marble; was capable of being cut away and transported in a wooden frame to any distance; and sometimes even tables were formed of it. (Vitruvius, ii. 8; Pliny, xxxv. 49.)

The process of varnishing the walls when coloured, Vitruvius terms (vii. 9) a Greek practice, called *καῦσις*, "a burning." When the wall was coloured and dry, Punic, or purified and bleached, wax, melted and tempered with a little oil, was rubbed over it with a hard brush; this was made smooth and even by applying a *cauterium*, or iron pan filled with live coals, to the surface, near enough to melt the wax: it was then polished with a linen cloth. [ENCAUSTIC PAINTING.]

Fresco was not generally practised by the early Italian painters, and it appears to have been first used in the 14th century, simply as a preparatory process, the work being finished in *tempera*. The earliest works in *buon fresco* are in the Campo Santo at Pisa (about 1390), in the church of Assisi, in the cathedrals of Orvieto and Siena, and in San Miniato and Santo Spirito at Florence. Thenceforward the practice of fresco improved with the progress of the art of painting, until it reached its greatest excellence in the hands of Michel Angelo, Raffaelle, and their contemporaries, whose greatest works were all executed in this manner. With the decline of the art, fresco fell gradually into disuse. Its revival dates from about 1816, when the young German painters, Cornelius, Overbeck, Veit, and Schnorr, undertook to paint with frescoes the Villa Bartholdy at Rome. Ludwig, then crown-prince, afterwards king of Bavaria, warmly patronised the new art, and at a large expenditure, continued through many years, afforded the young painters ample opportunities for a thorough study of the works and processes of the old masters; and, in the magnificent Glyptothek, the Ludwigs-Kirche, the new palace, and the Pinacothek, at Munich, of exercising their own powers on a colossal scale. With Hess, Kaulbach, and other German artists, these, the earliest practitioners, have succeeded in restoring the art to nearly all its former supremacy; and many of their paintings rival in purpose and magnitude, if not in power, the most important works of the great masters of Italy. Fresco has also been practised to a considerable extent in France, and some excellent works have been produced there. In our own country great attention was called to the process, by the recommendation of the Commissioners of the Fine Arts that the new houses of parliament should be adorned with fresco-paintings. As is well known, in pursuance of this recommendation, a large number of fresco-paintings have been executed with more or less success by artists of eminence in the house of lords, robing rooms, peers' and commons' corridors, and various chambers. Some of these are highly effective works, but as a rule English painters have not as yet acquired sufficient familiarity with the process to work in it with the necessary freedom and decision. Of the earlier frescoes, especially those of subjects from the English poets in the upper waiting hall, some have greatly faded or otherwise changed in appearance, owing as is believed to damp in the walls. In the frescoes recently executed, and now in course of execution, much greater precaution is taken to ensure their permanency. The example set in the new palace of Westminster has not hitherto been so extensively followed in this country as might have been anticipated. The principal frescoes since executed here have been a series in a garden saloon at Buckingham Palace; those by Mr. W. Dyce, R.A. (already distinguished by his frescoes in the new palace), above the altar at All Saints', Margaret Street; and the 'School of Legislation,' by Mr. Watts, which covers the north end of Lincoln's Inn Hall. This last is probably the largest fresco executed since the time of Michel Angelo, with the exception of the 'Last Judgment,' by Cornelius, in the Ludwigs-Kirche, Munich: the Lincoln's Inn fresco is 50 feet by 34; that at Munich, 60 feet by 30.

1. *Walls.*—We now proceed to give a more particular account of the processes employed in fresco-painting. Frescoes are painted on four different kinds of walls: in the old gothic buildings, on ashlar walls covered with a thin coat of plaster; in more recent buildings, on brick and rubble walls; and in some of the most recent edifices, on lath covered with various thicknesses of plaster. In many old buildings the walls as built were very uneven, and no attempt was made by the plasterer to correct a defect so detrimental to the appearance and preservation of a painting, through the settlement of dirt and the injury it undergoes in cleaning. The plaster is liable to fall away from ashlar walls, especially if the stones are large and the joints close, as in the cathedrals of Siena and Orvieto; in the church of Assisi, where the stones are small and not closely jointed, the plaster has a better hold and is generally still firm, but ashlar walls condense the damp and are the worst of all walls for frescoes; brick, rubble, and lath are much better, and nearly all equally good if well constructed. Mr. Wilson, then director of the Government School of Design, in his report to Her Majesty's Commissioners on the Fine Arts, respecting the state of the middle age frescoes and other mural paintings—to inquire into which subject he was expressly sent into Italy—ascertained upon what species of wall the various frescoes of the most eminent Italian painters were executed, and reported as to the actual condition of those works, with reference to the walls on which they are painted, and the result is, that those executed on brick are the most general, and in the best state of preservation: equality of surface being a great advantage which the brick wall has over the rubble wall. Many of the best of the old frescoes however are upon rubble walls, and unfortunately upon badly constructed walls of this description, as those of Santa Maria Novella at Florence, and St. Cecilia at Bologna. The older walls of the Vatican are of rubble, or of alternate courses of rubble and brick, or rubble and tufo, a coarse porous volcanic stone, and are thickly coated with rough-cast, or coarse plaster of sand and lime mixed. The 'Trionfo della Morte,' by Orcagna, in the Campo Santo at Pisa, is painted upon lath, and is the best preserved fresco there. By this provision his work was protected from the damp which rises from the soil, and that which infiltrates from the roof; the sea air therefore cannot have injured the other frescoes, or it would have injured this likewise. There are many frescoes at Florence and at Venice, on lath, and all are in tolerable preservation; many vaulted or coved ceilings are of lath, plastered above as well as below. The frescoes in the new palace at Westminster have been executed on lath, but in the most recent ones the laths have been fixed to a panel of slate 1½ inch thick, a space for air half an inch deep being left between the laths and the slate by means of battens at the ends: the method is shown by aid of diagrams in the 11th Report of the Commissioners of the Fine Arts.

2. *Plaster and Lime.*—The method of plastering the walls for painting has been nearly uniform in most ages. The walls of the baths of Titus at Rome are covered first with a layer about half an inch thick of coarse sand and lime; above this a thicker layer of lime and pozzolana, with an admixture of sand and pounded brick; the third and upper coat is of lime and pounded marble. The third loggia of the Vatican, painted by Giovanni da Udine, is much the same as this; the first layer upon the lath is a thin coat of coarse sand and lime, the second is also a thin coat of lime and pozzolana, and the third is of lime and marble-dust, but not finely pulverised.

In all plastering for fresco painting the lime should be rather old, even in the first coat or rough-cast; but it is indispensable in the last coat, or *intonaco*, upon which the painting is executed. Various directions are given by writers on art as to the proportions of lime and other materials for the several coats, and they all agree in essentials. The oldest writers are Cennino Cennini and Leon Battista Alberti. Cennini's 'Trattato della Pittura' was written in 1437, but was first published in Rome by the Cavaliere Trambroni in 1821; an English translation of it, by Mrs. Merrifield, was published in 1844. The work of Alberti, 'De Re Edificatoriâ,' though written after the treatise of Cennini, was published shortly after Alberti's death, in 1485, by his brother Bernardo.

Cennini recommends that both lime and sand should be well sifted, and if the lime be rich or recently slaked, that there should be two parts of sand to one of lime; that enough for fifteen or twenty days should be prepared at a time, and that it should be kept for some days to render it less caustic, for if too caustic, the *intonaco* will blister. Alberti speaks of three coats as necessary: in the first, or rough-cast, he recommends the use of pit sand and pounded bricks; in the second, or sand-coat, he recommends river sand; in the third coat, which should be white, he recommends pounded white marble instead of sand; but finely sifted well-washed river sand makes a superior *intonaco*: these three coats were called by the Italians—the *rinzaffato*, rough-coat; the *arriciato*, sand-coat; and the *intonaco*, the fresco ground. Cennini speaks only of two coats, both of which he terms *intonaco*. Similar directions in essentials are given by Armenini, in his treatise 'De' Veri Precetti della Pittura,' Ravenna, 1587; at the end of the treatise on perspective, 'La Prospettiva,' by Andrea Pozzo, Rome, 1693; and in still greater detail by Palomino, in his work 'El Museo Pictorico y Escala Optica,' Madrid, 1715. Various other writers also have given more or less concise directions for fresco painting, but they contain scarcely any information that is not given at greater length in the above-mentioned works, from which Sir C. J. Eastlake made several important extracts in an Appendix to the 'Report of the Commissioners on the Fine Arts' for 1842. What follows here from the directions of Cornelius, Hess, and other eminent contemporary fresco painters, from the same Report, agrees in every material point with the advice of those earlier practitioners in the art.

The selection of the limestone to be employed in fresco painting, both for the ground and for the white, is a matter of great importance; it should be nearly pure carbonate of lime, and should contain as few foreign materials as possible. The early Italian painters found Travertine the stone best fitted for the purpose; it is in great abundance in the Roman Campagna, being a deposit or calcareous sediment from the streams of water which run from the Apennines, which consist in Central Italy chiefly of a soft limestone. Travertine consists of a carbonate of lime, with an extremely minute portion of alumina and a trace of oxide of iron. Its lime is pure white. The lime used now by the Florentine fresco painters is so nearly pure carbonate of lime that no appreciable quantity of any admixture can be detected. The limestone used by the painters of Genoa is also of the purest white, and is extremely good; it contains about one-third carbonate of magnesia. The Genoese frescoes, notwithstanding their vicinity to the sea, are perfectly durable. The first fresco that was executed in Genoa, according to Soprani, is still in excellent preservation; it is the Annunciation of the Virgin, in Santa Maria di Castello, painted by Justus de Alemania, or Justus of Germany, in 1451. The lime used by the fresco painters of Munich is made of the marble pebbles brought down from the Bavarian Alps by the Isar. Excellent limestone for the purpose is found also in England, on Durdham Down, in the neighbourhood of Bristol, and in other parts. Analyses of all these and other varieties are given in the Reports of the Commissioners of the Fine Arts.

Modern fresco painters recommend the lime to be kept a much longer period than Cennini and other early writers direct. If used too fresh, it blisters, and sometimes turns the colours to a brownish red; its caustic quality requires to be mitigated, but not destroyed, before it is used. On this subject Sir Charles Eastlake's Report contains several scientific observations, upon the authority of Mr. R. Phillips, from which we learn that the non-caustic state of lime is arrived at when, by exposure to the air or by other means, it is restored to the state of a carbonate or has regained its maximum of carbonic acid. If buried and kept air-tight, it cannot acquire the carbonic acid which renders it non-caustic. Time therefore has no effect on pure lime, whether slaked or unslaked, provided it be not exposed to the air or some other source of carbonic acid.

The lime used for the *intonaco* in fresco painting must, however, not be entirely carbonated, or it would not set; a certain degree of causticity is necessary—how much, however, can be learnt probably by practice only; and this is the greatest practical difficulty in the art. The picture must be executed while the *intonaco* is wet or soft; no more work therefore ought to be commenced than can be completed within the time (a few hours) that the plaster requires to harden. Numerous joints are thus necessary in a large fresco, and the judicious painter will contrive that these joints shall be identical with the inner outlines of the parts of the figures and their draperies, or any other object, so as to be no disfigurement to the work.

Cornelius recommends the following mode of preparing the lime. A pit, lined with brick, is filled with clean burnt limestones, which, on being slaked, are stirred continually until the substance is reduced to an impalpable consistence. Clean river-sand is then spread over the surface, to the depth of a foot or more, and then the whole is covered with earth so as completely to exclude the air. It is allowed to remain in this condition for at least three years: it retains its moisture for many years. It is excluded from the air, for the reasons assigned above, that it may retain its causticity, and not become entirely carbonated. But there appears to be no real necessity for keeping the lime so long buried; and river-sand should be used with great caution. Wishing to employ a ground darker than the usual white intonaco for some of the paintings he was engaged on in the new palace, Mr. Dyce procured specimens of the dark gray sand of the river Lune in Yorkshire, and "the result was encouraging." But desiring to be assured as to its chemical properties, he applied to Professor Hofmann, who, on analysing it, discovered that the dark colour was attributable to the presence of iron pyrites, and pointed out that an "intonaco deriving its tint from such a cause, when exposed to the action of the atmosphere, is likely to crumble much sooner than one in which sand free from iron pyrites is employed." But as Sir R. Murchison observed, river sands nearly always "contain impurities and oxidisable substances which would be sure to affect the intonaco." "The analysis," continues Sir Roderick, "of the old Paduan frescoes (of Giotto) shows that there was scarcely a trace of iron in the Italian mixture, which was, I dare say, made up of the purest silicious sand which could be procured with one of the crystalline limestones or pure marbles of the country, nearly all of which contain some magnesia. The sculptors may aid the painters, and the *rejectamenta* of the former may prove the best possible material for mixing up with the pure white sand, for it is highly charged with carbonic acid. Besides, by this process one half of the material would be Italian, and possibly, if not probably, the very lime used by Giotto." (Eleventh Report.) This last is a hint well worth attending to.

3. *Execution of the Fresco.*—Cornelius recommends three years' interval between the rough coating of the wall and the commencement of the actual preparation for painting, unless the lime used in the first instance be very old, when between six and twelve months will be sufficient. Before laying on the *intonaco* the prepared ground must be repeatedly wetted with rain-water or boiled water, or still better, distilled water, until it will absorb no more; then a thin moderately rough coat of plaster of sand and lime must be laid over as much of the wet surface as can be painted in one day; as soon as this coat begins to set, in about ten minutes or so, another thin coat must be laid on with a wooden trowel, somewhat fatter, that is, with more lime and less sand, or with about equal parts of lime and fine river-sand; both layers together being scarcely a quarter of an inch thick. Upon this coat the fresco is to be painted: if the surface as left by the wooden trowel is found to be too smooth, it can be made slightly rough with a dry brush. This *intonaco* will be fit to paint upon in about a quarter of an hour: it is hard enough to receive the colour as soon as it will not yield to the pressure of the finger; if too soft, the wet brush will wash up the sand. The first process in executing the picture is to pounce or trace the outline of the allotted work, from the expressly prepared cartoon, of the same size as the fresco, upon the *intonaco* with a hard point (the artist must please himself as to the method of tracing); then the painting may be commenced in thin watery washes, from the finished coloured sketch, which must be placed so as to be conveniently seen while at work; for the process of fresco-painting should be simple copying; the mere execution requires so much attention, that it is necessary for the painter to be relieved of every other consideration. After the first wash is finished, an interval of twenty or thirty minutes should be allowed for the absorption of the water before commencing the second painting, otherwise in retouching and elaborating the design the surface would be washed up and the work destroyed. While the *intonaco* is wet, a repetition of the same tint will have the effect of a darker tint, as in water-colour drawing: the retouches for strengthening and rounding should be hatched, and, where great depth or force is required, repeated hatchings are necessary. The surface must be constantly kept moist (but not wet) while painting, or the superadded colour will not unite with what is beneath; the work is finished by glazings and washings. When the portion of the picture allotted for the day's work is completed, the superfluous portions of the *intonaco* should be carefully cut away. In the next day's operation the surface must be wetted as before, and the edging of the finished piece carefully moistened with a brush. If it should be necessary to leave the work for an hour or two, it may be kept moist by pressing a wet linen cloth against it, by means of a board padded and covered with a waxed cloth; the board may be propped against the wall by a pole from the ground.

If a piece of work should be unsatisfactorily executed, or accidentally damaged, it must be entirely cut away, and the whole operation be commenced afresh. A fresco cannot safely be retouched when dry, but if retouched the vehicle should be vinegar and the white of egg; this answers well for the shadows: the lights are sometimes heightened by crayons made of pounded egg-shells. It is useless, however, to retouch a fresco in the open air, as the rain would wash all retouches away; the fresco itself is not injured by rain.

The colours used in fresco-painting are all ground and mixed in water, boiled or distilled; they are chiefly earths; no vegetable and few mineral colours can be used with safety, but there is a mode of rendering vermilion durable. The white used is exclusively lime, which has either been well washed and long kept, or, by boiling and repeated manipulations and drying, is rendered less caustic. The following colours are used by Hess, the eminent German fresco-painter:—*yellow*, all kinds of ochres, raw siena; *red*, all kinds of burnt ochres, burnt siena, oxides of iron, and lake-coloured burnt vitriol; *green*, terra-vert, or Verona green, cobalt-green, and chrome-green; *blue*, ultramarine pure and factitious, cobalt. These colours are perfectly safe; chrome-yellow and vermilion are also used, but not in every case with success. Lime destroys all animal and vegetable colours.

The tints should be carefully prepared and kept in pots, and if a great quantity of any one tint should be required in one picture, it should all be prepared at once, as it is almost impossible to match tints exactly, as they are of different degrees when wet and when dry.

The brushes are of the ordinary materials, but should be somewhat longer than those used in oil-painting. In addition to hogs'-hair tools, small pencils of otter hair in quills are used: other hairs will not resist the lime, which burns and curls them. The palette, commonly made of tin, with an edge to prevent the colours from running off, should be covered with varnish, to preserve the tin from rust.

To know when to leave off is a great art in oil-painting, but in fresco it is of the utmost importance. On this subject Hess says, "If the touches of the pencil remain wet on the surface, and are no longer sucked in instantaneously, the painter must cease to work, for henceforth the colour no longer unites with the plaster, but when dry will exhibit chalky spots. As this moment of time approaches, the absorbing power increases, the wet brush is sucked dry by mere contact with the wall, and the operation of painting becomes more difficult. It is therefore advisable to cease as soon as these indications appear. If the wall begins to show these symptoms too soon, for example in the second painting, some time may be gained by moistening the surface with a large brush, and trying to remove the crust or setting that has already begun to take place: but this remedy affords but a short respite."

Fresco-painting as thus described is sometimes termed by Italians *buon-fresco*, to distinguish it from another method which they term *fresco-secco*, dry fresco.

Fresco-secco is practised at Munich as follows, as described in Mr. Wilson's report:—The plastering of the wall having been completed as for buon-fresco, the whole is allowed to dry thoroughly. Before painting, the surface of the *intonaco* must be rubbed with pumice-stone, and on the evening of the day before the painting is to be commenced, it must be thoroughly washed with water mixed with a little lime; it must be wetted again the next morning, and it is then ready for pouncing or tracing the outline, and painting; the wall must be kept constantly moist by means of a syringe. The colours used are the same as in *buon-fresco*, and the work is very durable. All fresco painters do not trace their outlines from cartoons, but it is the safest practice, and has been adopted by all the best masters. *Fresco-secco* is a good method for decorative painting, for which it is now much employed.

4. *Cleaning and transferring Frescoes.*—Frescoes are best cleaned with bread. The mouldy appearance which sometimes shows itself can be removed with a wet sponge, unless it arise from saltpetre in the walls, in which case there is no remedy. These injuries must be provided against in the construction of the walls: the vertical progress of damp may be intercepted by covering one of the lower courses of bricks or stones with sheet lead, which must be protected on each side by a coat of pitch; the wall may be then continued as usual. Frescoes may be safely washed with a soft sponge and water; vinegar and wine may likewise be used with safety; even frescoes that have been whitewashed over can be washed clean. The frescoes by Raffaelle, in the Stanze of the Vatican, though covered with nearly two centuries of dirt, were washed with wine by Carlo Maratti.

As many valuable frescoes, if left in their original localities, must have inevitably perished, through the bad construction of the walls, unfit situations, or from other causes, the invention of some mode of removing them from their objectionable situations became an object of great interest, and several very ingenious methods of transferring frescoes from walls have been devised, and often practised with success. Mr. Ludwig Gruner removed and transferred to canvas, in 1829, at Brescia, some frescoes by Lattanzio Gambara, in the convent of St. Eufemia, in the following manner:—the first process was to clean the wall perfectly; then to pass a strong glue over the surface, and by this means to fasten a sheet of fine calico upon it. The calico, being made fast by the glue to the irregularities of the wall, was itself covered with glue, and some strong linen glued over it. "In this state heat was applied, which caused the glue, even on the fresco, to sweat through the cloths, and to incorporate the whole. After this a third layer of strong cloth was applied on a new coat of glue. The whole remained in this state two or three days (the time required may vary according to the heat of the weather). The superfluous cloth extending beyond the painting was now cut off so as to leave a sharp edge: the operation of stripping or rolling off the cloths began at the corners above and below, till at last the mere weight of the cloth and what adhered to it assisted to detach the whole, and the wall behind appeared white, while every particle of colour remained attached to the cloth. To transfer the painting again to cloth, a stronger glue is used, which resists moisture, it being necessary to detach the cloths first used, by tepid water, after the back of the painting is fastened to its new bed."

Some frescoes by Paul Veronese, in the Morosini villa, near Castel Franco, were transferred by Count Balbi of Venice. Cloth was fastened to the wall by means of paste made of beer and flour, and rivetted to the irregularities of the surface by means of a hammer composed of bristles.

Cicognara, *Del Distacco dèlle Pitture a Fresco*, 1825, in 'Antologia di Firenze,' vol. xviii. num. 52; Baruffaldi, *Vita di Antonio Contri, Pittore e Rilevatore di Pitture dal Muro*, Venice, 1834; Förster, *Beiträge zur neuern Kunstgeschichte*, Leipzig, 1835; Cenni, *Sopra diverse Pitture staccate dal Muro e trasportate su Tela*, &c., Bologna, 1840; Eastlake, *Materials for a History of Oil Painting*, 1847, (chap. vi.); *Contributions to the Literature of the Fine Arts*; Mrs. Merrifield, *Original Treatises dating from the* 12th to 18th *centuries on the Arts of Painting*, 2 vols. 1849; Taylor, *Manual of Fresco and Encaustic Painting*, 1843; the *Appendices to the Reports of the Commissioners on the Fine Arts*, from the 2nd Report published in 1842, to the 11th published in 1858, which contain much important matter connected with fresco-painting, including many details on subjects to which there is not space in this article even to allude.

FRET, in musical instruments of the stringed kind, is a wire fixed in the neck, for the purpose of marking the exact part of the finger-board to be pressed for the purpose of producing certain sounds. Frets are now never applied to any instruments except guitars, lutes, &c.

FRIARS, from the French *frères*, a term in strictness meaning the brethren of a community, but more particularly applied to a new order of religious persons, who mostly sprang up at the beginning of the 13th century, and were encouraged in the hope of restoring respect to the monastic institution, the ample endowments of which had led it to degenerate from its primitive austerity, and yield to luxury and indulgence.

The friars consisted of Dominicans, Franciscans, Carthusians, Cistercians, Trinitarians or Maturines, Crossed or Crutched Friars, Austin Friars, and Bonhommes or Good Men. These last were brought into England by Edmund, earl of Cornwall, in 1283, and a colony of them was placed at Ashridge in Buckinghamshire. The Capuchins and Observants were distinctions of the Franciscan Friars.

Accounts of the principal orders will be found under their respective heads.

FRICTION. The rubbing together of two substances, in the course of which action (in mechanical operations) a resistance is developed to the motion of those substances. The resistance of friction is produced by the asperities, or unevenness, of the rubbing surfaces; for however perfect the polish of those surfaces may be, there are always irregularities of height, or of hardness, in the molecules of the respective bodies of a nature to allow some of the particles of the upper one to force themselves into the depressions, or softer particles of the lower, from whence they cannot be removed without the exercise of a force opposed to the continuance of motion. At the present day it is customary to consider Friction under two heads, the *Friction of sliding*, or that which is produced when the moving body passes constantly over the same part of the fixed surface, or *vice versâ*; and the *Friction of rolling*, or that which is produced when the parts of the surfaces of contact are constantly changing their relative positions.

Amontons, Bulfinger, Parent, Euler and Coulomb, were amongst the earliest writers on physics who treated the subject of Friction, and their researches have been confirmed and developed by the labours of Fergusson, Vince, Navier, Morin, &c. The laws deduced by these observers may be thus briefly stated.

1. Friction is proportional to the normal pressure which the surfaces of contact exercise on one another, but it varies according to the nature and the state of the surfaces of contact, and is independent of the velocity of movement, or of the extent of the surfaces. The above law is, however, limited in this sense, namely, that when the pressure exceeds a certain point, the surfaces are as it were driven into one another, and the friction of the bodies in motion increases without any apparent rule; it becomes in fact abrasion.

2. When bodies have been for some time in contact, especially if they should be of a compressible nature, the sliding friction will be found to be greater at the commencement of motion than at a subsequent period. A slight blow in the direction of the intended motion will produce a sufficient movement to obviate the effects of this temporary increase of resistance. The coefficient of friction is the term applied to the force which it is necessary to exert in order to overcome the resistance directly opposed to motion; and, as it is proportionate to the normal pressure exercised by the two surfaces in contact, it is expressed by the simple formula $f=\frac{F}{P}$, in which f= the coefficient required, F= the resistance ascertained experimentally; and P= the pressure. Elaborate tables of the coefficients of sliding and rolling friction have been drawn up by Morin; and others are quoted by Poncelet in his 'Introduction à la Mécanique Industrielle,' see also Claudel, 'Formules à l'usage des Ingénieurs,' &c.

3. The interposition of an unguent of any description modifies these laws in a very remarkable manner, so that it is necessary to calculate upon a particular coefficient of friction dependent upon the nature and state of the unguent, and upon its mode of supply, whenever any of this class of materials are used.

4. The friction of cylinders rolling upon a horizontal plane is in the direct ratio of their weights, and in the inverse ratio of their diameters.

5. In all cases in which solid bodies rest upon one another, there is an inclination of the surfaces of contact at which the bodies are susceptible of motion by the mere effect of gravity; and it is of the utmost importance in all the operations of applied mechanics to ascertain the precise value of this *angle of inclination*, or, as it is sometimes called, of this *limiting angle of resistance*. Morin's tables contain a series of practical observations on this subject; they have been translated in Moseley's admirable work, 'The Mechanical Principles of Engineering and Architecture.' The thrust of earthworks upon retaining walls is a special illustration of this problem, which will be discussed under RETAINING WALLS.

6. In practical mechanics, also, the effects of friction are in some cases modified by the resistance offered by the rigidity of the materials in motion; as, for instance, in the case of cords working over pulleys, or of bands working upon driving wheels. The particular laws of this class of actions will be discussed under RIGIDITY OF CORDS; and for the present it may suffice to say that the increase of resistance occasioned by the cord or band may be represented by a formula of two terms, one of which is a constant quantity, and the other the product of a constant quantity, or factor of the resistance divided by the resistance itself: so long, at least, as the same cord only is concerned. For different cords, the constants vary, within certain limits, as the squares of the diameters or of the circumferences of the cords, in respect to new cords, wet or dry; in respect to old cords, they vary nearly as the $\frac{3}{2}$ power of the diameters, or of the circumferences. The rigidity of cords only acts to increase the resistance in the portions of their length where they wind upon the pulleys.

Friction is considered, and sometimes practically resorted to, as a source of heat, for the inhabitants of the South Sea Islands obtain fire by rubbing two pieces of dry wood violently against each other. The heat developed by the friction of machinery in motion is one of the most serious causes of its deterioration; and it is on this account, nearly as much as upon account of the motive power lost through the resistance of friction when no lubricating materials are used, that it is necessary to provide for the continuous supply of fresh and cool lubricators. It may occasionally happen that the pressure, or weight, of the moving body may force out the greases ordinarily used from between the bearing surfaces, in which cases, heating, friction, or even abrasion, may ensue. It is therefore important to proportion the area of the bearing surfaces to the pressure in such wise as to prevent its attaining this limit; and, under any circumstances, to use the most fluid lubricators possible, as they will most easily be forced into the inequalities of the surfaces. Grease, for instance, is a better lubricator than water: oil than grease; and of oils it would appear that the mineral ones are better adapted to this use than either the animal or the vegetable ones.

FRICTION WHEELS. [Wheels.]

FRICTIONAL ELECTRICITY. [Electricity, Common, Frictional, or Franklinic.]

FRIDAY. [Week.]

FRIENDLY SOCIETIES. These institutions, which, if founded upon correct principles and prudently conducted, are beneficial both to their members and to the community at large, are of very ancient origin. Mr. Turner, in his 'History of the Anglo-Saxons,' notices them in these words: "The guilds or social corporations of the Anglo-Saxons seem on the whole to have been friendly associations made for mutual aid and contribution, to meet the pecuniary exigencies which were perpetually arising from burials, legal exactions, penal mulcts, and other payments or compensations." (See also Herbert's 'History of the Twelve Great Livery Companies,' vol. i., p. 1.)

In 1773 a bill was brought into the House of Commons for "the better support of poor persons in certain circumstances, by enabling parishes to grant them annuities for lives upon purchase, and under certain restrictions." The bill passed the Commons, but was rejected by the Lords. A bill with a similar object met with the like fate in 1780. A bill introduced in 1793 by the late Mr. George Rose passed into a law (33 George III. c. 54), which is known by his name, and was extensively acted upon. This act recited "that the protection and encouragement of friendly societies in this kingdom, for securing, by voluntary subscription of the members thereof, separate funds for the mutual relief and maintenance of the said members in sickness, old age, and infirmity, is likely to be attended with very beneficial effects," and it authorised persons to form themselves into a society of good fellowship, for the purpose of raising funds, by contributions or subscriptions, for the mutual relief and maintenance of the members in old age, sickness, and infirmity, or for the relief of the widows and children of deceased members. A committee of members was authorised to frame regulations for the government of the society, which regulations, after being approved by the majority of the subscribers, were to be exhibited to the justices in quarter-sessions, and if not repugnant to the laws of the realm, and conformable to the true intent and meaning of the act, were to be confirmed and made binding upon the subscribers.

Among other provisions, it was allowed to impose reasonable fines upon such members as should offend against the regulations; such fines to be applied to the general benefit of the society. By this act it was declared unlawful "to dissolve or determine any such society, so long as the intents or purposes declared by the society remain to be carried into effect, without the consent and approbation of five-sixths of the then existing members, and also of all persons then receiving or entitled to receive relief from the society on account of sickness, age, or infirmity." Societies thus constituted were relieved from the payment of certain stamp-duties, and were empowered to proceed for the recovery of moneys, or for legal redress in certain cases, by summary process, without being liable to the payment of fees to any officer of the court; and to aid them, the court was required to assign counsel to carry on the suit without fee or reward.

In 1795 an act was passed which extended the privileges of Mr. Rose's act to other "benevolent and charitable institutions and societies formed in this kingdom for the purpose of relieving widows, orphans, and families of the clergy and others in distressed circumstances." Several other acts were passed between 1795 and 1817 affecting the proceedings of these societies, but not in any matter of importance. In the last-mentioned year the "Savings' Bank Act" was passed, and under its provisions the officers of friendly societies were allowed to deposit their funds in any savings' bank, by which means they got security for their property and a higher rate of interest than they could otherwise obtain. This act has been of essential benefit to these associations. Another law, making provisions for the further protection and encouragement of friendly societies, and for preventing frauds and abuses in their management, was passed in 1819; but as this and all other acts previously passed with the same object were repealed and superseded by the act of 1829 (10 Geo. IV. c. 56), which, with two acts passed in 1832 and 1834 (2 Wm. IV. c. 37, and 4 & 5 Wm. IV. c. 40), contain the law as it now stands for the regulation of friendly societies, it is unnecessary to detail here the alterations effected in 1819.

In the years 1825 and 1827 select committees were appointed by the House of Commons to consider the laws of friendly societies. The reports made by these committees have thrown considerable light upon the subject, and prepared the way for the enactment of 1829, already mentioned, which, with the subsequent acts of 1832 and 1834, we now proceed to analyse.

The law of 1829 (10 Geo. IV. c. 56), in the first place, authorises anew the establishment of societies within the United Kingdom, for raising funds for the mutual relief and maintenance of the members. The members of such societies are to meet together to make such rules for the government of the same as shall not be contrary to the intent of the act nor repugnant to the laws of the realm, and to impose such reasonable fines upon the members who offend against any of such rules as may be necessary for enforcing them; and these rules, which must be passed by a majority of the members present, may be altered and amended by the same authority.

But before these original or amended rules shall be confirmed by the justices of the county at the general quarter-sessions, they must have inserted in them a declaration of the purposes for which the society is established, and the uses to which its funds shall be applied, stating in what shares and proportions, and under what circumstances any member of the society or other person shall be entitled to the same; and further, it is required that the rules so passed "shall be submitted, in England and Wales and Berwick-upon-Tweed, to the barrister-at-law for the time being appointed to certify the rules of savings' banks; in Scotland, to the lord-advocate or any of his deputies; and in Ireland, to such barrister as may be appointed by her Majesty's attorney-general in Ireland, for the purpose of ascertaining whether such rules are in conformity to law and to the provisions of this act." The officers here mentioned are respectively to settle such rules, and make them conformable to law and to this act of parliament, and to give a certificate of this regulation having been complied with. The rules so certified are then to be deposited with the clerk of the peace for the county wherein the society is formed, and by him to be laid before the justices at quarter-sessions, who are required to confirm the same, after which the rules and certificate are to be filed with the rolls of the sessions of the peace, and a certificate of such enrolment, signed by the clerk of the peace, is to be sent to the society. If the barrister or other officer above mentioned shall refuse to certify the rules offered for his approval, the society is allowed to submit the same to the court of quarter-sessions, together with the reasons assigned for refusal, when the justices may, if they see fit, confirm the rules, notwithstanding the disapproval of the revising officer.

Before these directions are complied with, no society is entitled to enjoy any of the privileges or advantages communicated by the act; but when the rules shall have been enrolled, and until they shall have been altered and the like confirmation shall have attended such alteration, they shall be binding upon the members of the society, and a certified copy of them shall be received in evidence in all cases. The treasurer of each society must give bond to the clerk of the peace for the county, with two sufficient sureties, for the faithful performance of his trust, and must, on the demand of the society, render his accounts and assign over the funds of the society at the demand of a meeting of the members. The property of the society is to be vested in the treasurer or trustees of the society, who may bring and defend actions, "criminal as well as civil, in law or in equity," concerning the property, right, or claim of the society, provided they shall be authorised to do so by the vote of a majority at a meeting of the members.

In case any person shall die intestate whose representatives shall be entitled on his account to receive any sum from the funds of the society not exceeding 20*l.*, the treasurer or trustees may pay the money to the persons entitled to receive the property of the deceased, without its being necessary to take out letters of administration.

It is not lawful to dissolve any friendly society, so long as any of the purposes declared in its rules remain to be carried into effect, "without obtaining the votes of consent of five-sixths *in value* of the then existing members, and also the consent of all persons then receiving or then entitled to receive relief from such society; and for the purpose of ascertaining the votes of such five-sixths in value, every member shall be entitled to one vote, and an additional vote for every five years that he may have been a member, provided that no one member shall have more than five votes in the whole."

The rules of the society are to contain a declaration whether, in the event of any dispute or difference arising between the society and any one or more of its members, the matter shall be referred to the decision of a justice of the peace or of arbitrators; if to the latter, the arbitrators must be chosen or elected in sufficient number at the first meeting of the society which shall be held after the enrolment of its rules; they must not be in any way interested in the funds of the society; and whenever the necessity for their employment shall arise, a certain number, not exceeding three, are to be chosen by ballot from among the arbitrators for the settlement of the dispute, and justices are empowered to enforce compliance with the decision of the arbitrators. If the rules of the society direct the application, in cases of disputes, to justices of the peace, any justice is empowered to summon the person against whom complaint is made, and any two justices may hear and determine the matter, their sentence or order being final and conclusive. Minors, if they act with the consent of parents or guardians, may become members of friendly societies, having authority to act for themselves on the one hand, and being held legally responsible for their acts on the other.

A statement, attested by two auditors of the funds belonging to each society, shall be made annually to its members, every one of whom may receive a copy of the statement on payment of a sum not exceeding sixpence.

Every friendly society enrolled under this act is obliged, within three months after the expiration of every five years, to transmit a return of the rate of sickness and mortality, according to the experience of the society during the preceding five years, such returns to be made in a prescribed form to insure uniformity. These returns are directed by 4 & 5 Will. IV. c. 40, to be addressed to the barrister appointed to certify the rules of friendly societies, London.

The provisions of the act of 1834 (4 & 5 Will. IV. c. 40) are for the most part confined to matters of regulation which it is not necessary to notice here.

The following are among the benefits derived from a Friendly Society being enrolled under the Geo. IV. c. 56, as amended by the 4 & 5 Wm. IV. c. 40:—1. The rules are binding, and may be legally enforced; 2. Protection is given to the members, wives and children, &c., in enforcing their just claims, and against any fraudulent dissolution of the society; 3. The property of the society is declared to be vested in the trustee or treasurer for the time being; 4. The trustee or treasurer may, with respect to property of society, sue and be sued in his own name; 5. Fraud committed with respect to property of society is punishable by justices; 6, Court of Exchequer may compel transfer of stock, &c., if officer of society abscond or refuse to transfer, &c.; 7. Application may be made to Court of Exchequer by petition, free from payment of court or counsel's fees, &c.; 8. Disputes settled by reference to justices or arbitrators—order of justices or award of arbitrators final; 9. Power to invest their funds to any amount in savings' bank; 10. Power to invest their funds with the commissioners for the reduction of the national debt, and to receive interest at the rate of 3*l.* 0*s.* 10*d.* per cent.; 11. Priority of payment of debts, in case officer, &c., of society become bankrupt, insolvent, has an execution, &c., against his property, or dies; 12. In case of death of members, payment may be made of sum not exceeding 20*l.*, without the expense, &c., of obtaining letters of administration; 13. Members are allowed to be witnesses in all proceedings, criminal or civil, respecting property of society; 14. Exemption of all documents, &c., from stamp-duty.

Societies thus constituted and privileged must be acknowledged to be a great improvement upon the old benefit clubs. Before these societies were regulated by statute, temptation was held out to obtain members by the smallness of the contributions, which proved in the course of years wholly inadequate to answer the demands that were then sure to arise, although the income of the society had at first, while the members continued young, been sufficient for the purpose. The mischief thus fell upon them when they had become old and infirm, and had no means of relieving themselves from it; this evil is now prevented by the compulsory adoption of tables prescribing such rates of contributions and allowances as experience has demonstrated to be sufficient and equitable.

By the 10 Geo. IV. c. 56 (as amended by the 4 & 5 Wm. IV. c. 40), friendly societies may be formed for providing relief to members, their wives, children, relations, or nominees, in sickness, infancy, advanced age, widowhood, or other natural state of contingency whereof the occurrence is susceptible of calculation by way of average, or for any other purpose which is not illegal; the rules therefore may now provide for relief in case of loss by fire, or by shipwreck; substitutes if drawn for the militia; a weekly allowance if reduced to a workhouse, imprisoned for debt, and for payment towards the expenses of the feast, &c. &c.; but, for all such purposes, the contributions must be kept separate and distinct from the payments which may be required, on account of relief in case of sickness, infancy, advanced age, widowhood, or other natural state of contingency, susceptible of calculation by way of average; or the charges may be defrayed at the time by extra subscription of the members. The money payable on the death of a member may be received by any person nominated by such member, and is not confined to his wife, child, or relation.

It is unnecessary to give the tables of contributions required from members of friendly societies, in order to insure to their members the benefits of such institutions, as every information respecting the establishment of friendly societies may be obtained, free of expense, on application, through a post-paid letter, to the "Barrister appointed to certify the Rules of Friendly Societies, London."

On the 20th of November, 1858, the number of friendly societies which had direct accounts with the commissioners for reduction of the national debt was 571, and the amount of their deposits was 980,354*l.* There were besides, at the same date, 9994 friendly societies, which had the sum of 1,562,784*l.* invested in savings' banks.

Since the passing of the Act of 1793 to the end of 1858, there had been enrolled and certified 28,550 friendly societies, of which 6830 had then ceased to exist, and several more ceased in 1859, chiefly from the decreased number of members, and from their growing age without the admission of younger members. A large number of these societies exist, also, of which the rules are not certified, nor are they enrolled, and the parliamentary report expresses its belief in the unsoundness of many of them, owing to the insufficiency of the contributions.

FRIENDS. [Quakers.]

FRIESLAND GREEN. [Green, *Brunswick green.*]

FRIEZE. [Column; Greek Architecture.]

FRIGATE. [Ship.]

FRIGIDARIUM. [Bath.]

FRISIANS, a people of Germany, who formed part of the nation of the Ingævones. Their name has been by some derived from the low German word "fresen," to shake or tremble, in allusion to the nature of their country, the soil of which is an unstable or shaking moor. They were divided into Frisii Minores, who inhabited the lands north of the island of the Batavi—the present provinces of Oberyssel, Gelders, and Utrecht, and the greater part of the province of Holland, inclusive of the Zuidersee, which at that time was mostly dry land; and the Frisii Majores, who inhabited the land between the Yssel, Ems, and the country of the Bructeri—that is, the present provinces of West Friesland and Groningen. The old Rhine separated them from the Batavi, and the Ems from the Chauci. According to Tacitus ('Ann.' ii. c. 24) they were the most steadfast allies whom the Romans possessed in this quarter; they aided Drusus and Germanicus in their campaigns against the Cherusci, and saved the Roman fleet from destruction at the mouth of the Ems. But this state of amity was broken off upon the Romans making an attempt to treat them as subjects; they thenceforward became declared enemies of Rome, and razed, with one exception, all her strongholds in these parts, having in the 28th year A.D., when Olennius was the Roman lieutenant, turned upon the Romans, slain about 900 of them near the woods of Baduhenna, and freed themselves from their dominion. (Tacit. 'Ann.' iv. c. 72, 73.) Corbulo, the Roman general under Claudius, A.D. 47, reduced them to obedience, and Nero drove them out of some districts on this side of the Zuidersee, which they had invaded. (Tacit. 'Ann.' xiii. c. 54.) From this period until the 4th and 5th centuries, when they appear as members of the great confederacy of the Saxons, no mention of them occurs. We find them at this time holding the sea-coasts from the Schelde to the Elbe and Eyder, whence it has been conjectured that a variety of tribes were then comprehended under the name of Frisians. They now passed over into Britain, in company with the Angles and Saxons, and aided them in its conquest. Under the emperor Julian they made themselves masters and retained possession of the island of the Batavi, on which spot they were sorely humbled by Pepin, major-domo of the Franks, who put Radbod their king to flight, and wrested the whole of their western lands from them as far as the mouths of the Rhine. Poppo, Radbod's successor, made a fruitless attempt to recover the lost territory, and was driven back by Charles Martel. Charlemagne hereupon brought the eastern dominions of the Frisians under subjection, and appointed his own dukes over them, whose office subsequently merged into that of chieftain (häuptling). The result of continued struggles for the mastery between these chieftains, who called themselves counts, was, that count Edzard prevailed, and established himself in that part called East Friesland, in 1458. In 1657, count Enno acknowledged it as a fief of the empire under the emperor Ferdinand, and was raised by him to the dignity of a sovereign prince; but both his power and that of his descendants was jealously limited by the national states. The last prince died in 1744, and by virtue of an imperial grant in 1690, Prussia took possession of East Friesland. It was wrested from her in 1808, and transferred to Holland; in 1810 it became a province of the French empire; in 1813 Prussia recovered it, and in 1815 she ceded it to Hanover.

The western part of the Frisian territory, or West Friesland, is a province of the kingdom of Holland.

The ancient Frisians resembled the Germans in their habits and mode of living, and according to Tacitus, the only tribute they could afford to pay the Romans consisted of skins. They were governed by two princes, whose authority was extremely confined. Their descendants are settled among the small islands on the western coast of the duchy of Schleswig, and preserve not only the name of Frisians, but many vestiges of their customs and dress.

FRIT. [Glass.]

FRONDE, the name of a political faction in France during the minority of Louis XIV., which was hostile to the prime minister, Cardinal Mazarin, and to the queen regent, who supported him. In consequence of some disputes between the parliament of Paris and the court, the cardinal ordered the arrest of the president and of one of the councillors of the parliament in August, 1648, and this act was the signal of a civil war. The party opposed to the court affected to declare themselves not against the queen's government, but only against the cardinal, whom they attacked by accusations and lampoons, from which they derived the name of "Frondeurs," "censurers," or "jeerers." They had for leaders the Duke of Beaufort, the Duke de Némours, the Prince of Conti, the Duke de Vendôme, the Abbé de Retz (afterwards cardinal), Marshal Turenne, and other men of the first rank, as well as ladies,—among others the Duchesse de Longueville, who was a most conspicuous and violent partisan. The people of Paris took part with the Frondeurs; they drew chains across the streets, attacked the troops, and obliged the queen to liberate the two members of the parliament. This was called "the day of the barricades." A kind of truce took place; but the parliament continued refractory, the court hostile, and the people tumultuous; and the queen regent, seeing herself obliged, in January, 1649, to remove from Paris with her son to St. Germain, charged the Duke of Orleans and the Prince of Condé with the task of reducing Paris by blockade. Louis XIV. was then little more than ten years of age, but he never forgot the humiliation of being obliged to leave his capital, and this was the first cause of his subsequent hostility towards the parliament. That court, in the mean time, exercised sovereign power in the capital, levied troops, and passed a resolution declaring Cardinal Mazarin a public enemy, and outlawing him. ('Histoire du Parlement de Paris,' Amsterdam, 1769.) After some fighting in the neighbourhood of Paris a truce was made, a general amnesty was granted by the queen, the parliament retained full liberty to assemble, and the queen, king, and minister re-entered Paris in the month of August. The disturbances, however, continued in the provinces, especially in Provence and Guienne, where the local parliaments resisted the authority of the respective royal governors. In 1650 the queen, hurt by the overbearing tone and high pretensions of the Prince of Condé, made her peace with some of the Frondeur leaders, and caused the princes of Condé and Conti to be arrested. Upon this, the Duchess of Longueville, Marshal Turenne, and others, raised the standard of revolt in the provinces, and were joined by the Spaniards from Flanders. The war, which now assumed a more serious aspect, continued till 1653, when Turenne made his peace with the court, and Mazarin returned in triumph to Paris. [CONDÉ, LOUIS DE in BIOG. DIV.]

FRONTISPIECE, the front or principal face of a building; the front view; anything seen in or at the front, Johnson says "id quod in fronte conspicitur." Hence, by a figure, we call the engraved title of a book, or the print which faces the title-page, a frontispiece.

FROST. [FREEZING.]

FRUCTOSE. [SUGAR.]

FRUIT, in botanical language, signifies that part of a plant in which the seed is lodged, whatever its size, colour, or texture may be, so that the seed-like grain of a sage, the grain of corn, the nut of a chestnut, the dry capsule of a lilac bush, are as much fruits as those of a peach, an apple, or a pine-apple. In the ordinary acceptation of the term however the word fruit is exclusively applied to seed cases which are eatable, and generally to such as require no preparation to render them fit for food.

The eatable fruits known in this climate are of so much importance to the comfort as well as luxury of society, that without entering much into details we shall here introduce some general observations, which will inform our readers what are the kinds most deserving of cultivation in select or confined gardens. In doing this we have the advantage of reproducing in a condensed form the important results of the laborious and costly investigations conducted for so many years in the garden of the Horticultural Society of London at Turnham Green. These have already been made known to the public in the second edition of the 'Catalogue of Fruits,' cultivated in that establishment; and our only task is to make a judicious selection from the thousands of varieties included in the Society's list.

The species of cultivated fruits are far from numerous; and most of those of the temperate regions have been introduced, at one period or another, into Britain. The genera from which these have sprung are comparatively few, and chiefly included in the natural orders Rosaceæ, Vitaceæ, Urticaceæ, and Grossulaceæ. To the first of these are to be referred the genera producing the species called apples, pears, plums, cherries, apricots, peaches, and nectarines, quinces, medlars, raspberries, and strawberries; to the second, the vine; to the third, the fig and mulberry; and to the fourth, the gooseberries and currants. Moreover there are chestnuts and filberts belonging to Corylaceæ; walnuts to Juglandaceæ, and the melon and pine-apple respectively to Cucurbitaceæ and Bromeliaceæ.

In this place we shall briefly enumerate what may be considered the most valuable varieties of each as objects of cultivation.

Apples are the most numerous class in cultivation. It has been conjectured that they were brought to this country by the Romans; but it is doubtful whether the varieties then introduced would succeed in this climate, presuming on the fact that the *Malo di Carlo*, well known as being so exceedingly beautiful and delicious in the North of Italy, has, in one of our finest English summers, proved pale and insipid, and that the apples of the South of Europe are generally worthless in England. A hardier breed, it is more than probable, was introduced by the Normans, especially of such as were suited for the manufacture of cider.

Apples are usually divided into three principal sorts, according as they are fitted for dessert, for kitchen use, or for cider. For dessert, the following are early varieties: Early Red Margaret, Early Harvest, Oslin, Kerry Pippin, and Summer Golden Pippin. In succession to these, the Wormsley Pippin, King of the Pippins, Golden Reinette, Ribston Pippin, Court of Wick, Pearson's Plate (a remarkably handsome dessert apple), Golden Harvey (one of the very highest excellence), Hughes's Golden Pippin, Herefordshire Pearmain, Lamb Abbey Pearmain, Court Pendu plat (which blossoms late, thereby escaping the spring frosts), Reinette du Canada, Old Nonpareil, and Scarlet Nonpareil. For early kitchen use: Dutch Codlin, Keswick Codlin, Hawthornden, Nonesuch, which last deserves particular notice on account of its beautiful transparency when made into apple jelly, for which purpose it is the best sort known. For winter and spring use, from many excellent varieties, the following are selected: Blenheim Pippin (which may be also used at dessert), Dumelow's Seedling, Bedfordshire Foundling, Alfriston, Gloria Mundi, Royal Russet, Brabant Bellefleur, Northern Greening, Norfolk Beaufin (from which the "Beaufins," or "Beefins," so generally to be seen in the London shops, are prepared), and French Crab, which will keep above a year. For cider, Siberian Bitter-Sweet, Foxley, Red Streak, Fox Whelp, Golden Harvey, Coccagee, Hagloe Crab, and Cooper's Red Streak, are amongst the most celebrated.

Of the varieties of *Pears*, few, till lately, have originated in this country; most of the kinds in former cultivation were from France, but they generally required the protection of walls. The greater intercourse with the Continent consequent upon the establishment of peace in 1815 led to the introduction of a number of new and hardy varieties of this fruit from Belgium, where its cultivation and improvement had been, and still are, attended to with great assiduity. These new varieties, with some of equal merit, and even superior hardiness, raised at Downton Castle, in Herefordshire, now compose the principal part of the most select lists, and are at the same time rapidly excluding the older French varieties from cultivation.

Pears are divided into three classes—dessert, kitchen, and perry. The following are amongst the finest. For dessert: Citron des Carmes, Jargonelle (which requires a wall), Summer St. Germain, Ambrosia, Fondante d'Automne, White Doyenné (if grown as an open standard), Seckle, Louise Bonne (of Jersey), Marie Louise, Beurré Bosc, Gansel's Bergamot (which also requires a wall), Duchesse d'Angoulême, Beurré Diel, Nelis d'Hiver, Althorp Crassane, Winter Crassane, Napoleon, Glout Morceau, Passe Colmar, Knight's Monarch, Neplus Meuris, Easter Beurré, Beurré Rance. These are enumerated in their order of becoming fit for use. For kitchen use: Bezi d'Heri (which is excellent for stewing, and very free from grittiness), Bequêne Musque, Spanish Bon Chrétien, Double de Guerre, Catillac, Uvedale's St. Germain. For perry: Oldfield, Barland, Longland, Teinton Squash.

The best varieties of *Plums* for the dessert are, the Green Gage, Washington, Reine Claude, Violette, Drap d'Or, Kirke's, Coe's Golden Drop, Blue Imperatrice. For kitchen use: Orleans, White Magnum Bonum, Shropshire Damson, which last is excellent for preserving, as are also the St. Catharine, Coe's Golden Drop, Green Gage, and Quetsche; the latter is the sort of which the German Prunes of the shops are made, by slow and repeated drying in an oven.

Cherries, it is said, were first cultivated in this country at Sittingbourn, in Kent, where they are supposed to have been introduced about the time of Henry VIII. That county is still famous for a sort called the Kentish Cherry, identical with some of the varieties of the Montmorency cherries of the French. They are round, bright red, and acid, and much used for pies. They have also the peculiar property of the stalk adhering so firmly to the stone that the latter may be drawn out without breaking the skin, except at the base. The fruit is then dried in hair sieves in the sun, or otherwise placed in a gently heated oven; the cherries will then keep for a year, and have the appearance of raisins. The best cherries for dessert are the Elton, Downton, May Duke, Royal Duke, Knight's Early Black, Early Purple Guigne, Bigarreau, Florence. For preserving, the Kentish and Morello are best.

Apricots in cultivation are of few varieties compared with any of the preceding kinds of fruits, and of those the most useful are the following: Large Early, Breda, Moorpark, Royal, and Turkey. The Breda is the best for standards; and when the season is favourable, the fruit on such, although smaller than that grown against a wall, is, notwithstanding, higher flavoured. A variety called the *Musch-Musch* may be noticed, although not recommended for cultivation in this climate. It is the sort grown in the oases in Upper Egypt, where it produces in great abundance, the fruit being dried, and in this state forming an article of commerce for exportation. The apricot blossoms earlier than any other fruit-tree cultivated in this country: hence, most probably, it was called Precocia among the Romans, a corruption of which name is traceable in the modern one of apricot. In consequence of the tree blossoming so early, its blossoms, particularly in the case of young trees, are extremely liable to drop off in setting. This is not to be wondered at, when it is considered that the ground is frequently at the time (March) in as cold a state as at any period of the whole season, neither the sun's heat nor the warm rains having reached so far below the surface as to warm the soil in contact with the roots; and thus, whilst the latter are in a medium perhaps a little above freezing, the tops, exposed to a bright sun against a wall, are at that period of the season occasionally in a temperature as high as 90° or 100° Fahr. The injurious effects of this disparity must be sufficiently obvious to every one, and the only remedy to be adopted is to have a very complete drainage below the roots, and the whole soil of the border, not retentive, but of a pervious nature. If it could also be kept perfectly dry previous to the commencement of vegetation, and then only allowed to receive the rain when warm, avoiding the cooling effects of melting snow and hail, the tree would thus be placed under circumstances comparatively more natural.

Peaches and *Nectarines* require the aid of a wall to bring them to perfection in this climate; and in the more northern counties of Britain the protection of glass is also requisite. They likewise rank among the kinds of fruits which are considered of sufficient value to be forced. A selection of the best varieties of peaches is as follows: Noblesse, Red Magdalen, Royal George, Grosse Mignonne, Belle Garde, Late Admirable. The two very best nectarines are the Elruge, which has little or no red at the stone; and the Violette Hâtive, the flesh of which is rayed with red near the stone: this serves as a principal distinction between these two varieties. For the sake of variety, the Pitmaston Orange and the White Nectarine may also beincluded. A selection of peaches for forcing may consist of the Bellegarde, Noblesse, Grosse Mignonne, Royal George, Royal Charlotte, and Barrington. Nectarines for the same purpose are the Elruge and Violette Hâtive.

The best variety of *Quinces* is the common one. The Portugal quince is distinct; but its fruit does not ripen so well in this climate as the common quince. Its wood, however, swells more in conformity with that of the pear, and it therefore is preferable as a stock for pears.

The principal varieties of the *Medlar* are the Large or Dutch, the Upright or Nottingham, and the Stoneless. The first is esteemed for its size, and sometimes for the form of the tree, on account of the rustic crooked appearance which it assumes: the second is of better quality as regards flavour; and the third is small without stones or seeds, and keeps longer than the others.

Raspberries, compared with many of the fruits mentioned above, differ little in their character as cultivated varieties from that of the botanical species *Rubus idæus*, from which they have arisen. For instance, the difference between the wild sloe and the green gage is very great; whereas the wild raspberry growing in the woods differs only slightly in flavour, and not widely in size and form, from those cultivated in gardens. Good varieties are the Red Antwerp, Yellow ditto, Barnet, Cornish, and Red Globe.

Strawberries are now considerably reduced in regard to the number of varieties in cultivation. By the introduction of "Keen's Seedling," the very coarse sorts have been mostly banished even from the streets of London; this variety having proved the best of all for the market, combining very good flavour with the properties of being of a large size and very prolific. Other varieties deserving cultivation are the Grove End Scarlet, Roseberry, American Scarlet, and, where wanted for confectionary, the Old Scarlet, which retains a fine colour; Downton, Elton, Old Pine, Prolific or Conical Hautbois, and the Large Flat ditto. The alpine and wood strawberries require to be occasionally renewed from seeds; the best varieties are the Red Alpine and the White Alpine. Keen's Seedling, Roseberry, and Grove End Scarlet, are proper for forcing.

Grapes are brought to high perfection in this country, by the aid of hothouses; in favourable situations some kinds ripen pretty well, even on walls in good seasons: but open vineyard culture is not practised to any extent in England at the present time, nor is it likely ever to become profitable. Varieties of wine grapes therefore need not be noticed here, farther than by stating that they are very numerous; many of them form small compact bunches like the "Miller's Burgundy," which is indeed one of them, and is the sort of black cluster grape with woolly, mealy leaves, commonly seen on the walls of houses near London. The following are suitable for a vinery:—Black Frontignan, Black Prince, Black Hamburg. West's St. Peter's, Black Morocco, Red Frontignan, White ditto, Grizzly ditto, Royal Muscadine, Chasselas Musqué, White Muscat of Alexandria; the last requires a strong heat. For walls, perhaps none fruits better, or forms a handsomer bunch than the Royal Muscadine; it is preferable to the Sweetwater, which generally forms a ragged bunch in consequence of a great number of the berries being small and abortive; the Black Prince and Esperione will sometimes succeed; and the Early Black July and Burgundy Black Cluster will ripen still better, but the bunches of the latter are very small.

The only fruits still remaining to be noticed, the varieties of which are of any importance, are figs, gooseberries, and currants, and pineapples.

In some parts of England the *Fig* bears in the open air; but in order to ensure its doing so, a warm, or more strictly speaking, a dry subsoil is absolutely necessary, whether it be grown as a standard in the open ground or against a wall, or forced under glass. Wherever the soil is retentive of water, it will retain the coldness of winter till late in the spring. In fact, if the subsoil be very wet, its temperature will approximate to that of spring water, which in England is little above 50° Fahr. throughout the whole year; an amount of cold which the roots of the fig are certainly not accustomed to in summer in its native climate in Asia and Barbary, or even where it has been naturalised in the South of Europe. Or, if the springs should fall so low during summer, as to leave the roots of the fig tree unaffected by their presence, the temperature of the surface will be suddenly raised by the first rain that falls. This often takes place towards the end of summer, and a superabundant growth ensues, too late for being completed before winter. Figs succeed well in Sussex, where the subsoil is chalk, and the rain passes off as it falls; and in preparing borders for it, the whole should be composed of such materials as are pervious to water. Some of the finest varieties of figs for this climate are the Brown Turkey, Brunswick, White Marseilles, Nerii, Pregussata, White Ischia, Brown Ischia, Yellow Ischia. The Brown Turkey is well adapted for forcing, for which purpose the Pregussata, White Marseilles, and the White, Brown, and Yellow Ischias are also proper.

Gooseberries are brought to greater perfection in Britain than in any other country. The varieties are numerous, and many of them have been raised in Lancashire, chiefly by the manufacturing population, with a view to prizes. It is to be regretted that the latter have generally been awarded solely with reference to weight; hence a number of large but coarse sorts have been brought into cultivation. In making the following selection, flavour and not size has been kept in view.

Fruit, red: Red Champagne; Red Warrington; Keen's Seedling Warrington; Rough Red, used for preserving; Red Turkey; Rob Roy; Ironmonger. *Fruit, yellow:* Yellow Champagne; Early Sulphur; Rumbullion, which is much used for bottling. *Fruit, green:* Early Green Hairy; Pitmaston Green Gage; Green Walnut; Parkinson's Laurel; Massey's Heart of Oak; Edwards's Jolly Tar. *Fruit, white:* White Champagne; Early White; Woodward's Whitesmith; Taylor's Bright Venus; Cook's White Eagle; White Honey.

The varieties of *Currants* preferable for cultivation are very few. Of black currants, the Black Naples and the Black Grape are the best. The White Dutch, Red Dutch, Knight's Sweet Red, and Knight's Large Red, are the best sorts of white and red currants.

The *Pine Apple* is the only tropical fruit which is cultivated to any extent in this country. The best varieties are the Queen, Moscow Queen, Black Jamaica, Brown Sugarloaf, and Black Antigua; the Enville and White Providence are cultivated more for their size than flavour.

FRUITS, PRESERVATION OF. The apple and pear, the two staple fruits of this country, are of so much importance to great numbers of persons, that we shall not dismiss this subject without giving some information concerning the best means of preserving them during the autumn and winter; for it is an object of no little moment to be able to prolong the duration of the season of these fruits even for a single month.

A few early varieties may be eaten from the tree, or when recently gathered; but the greater and by far the most valuable portion require to be kept for some time until they acquire a proper degree of mellowness: thus, most pears are extremely hard when gathered; some even remain so during the winter, and only become melting, or of a buttery consistency, in the spring. Apples, although it is their property to remain a long time nearly as crisp as when gathered, yet are at first too acid for the dessert, and require to be stored up in the same manner as pears, until their juices acquire a rich sugary flavour. Many varieties indeed permanently retain their acidity, but such are only proper for culinary purposes, for which indeed their briskness renders them eligible.

With regard to the gathering and storing of apples or pears, having in view their most perfect preservation, it is necessary that the gathering should be performed in all cases when the trees and fruit are perfectly dry. No precise time can be specified as to the period of the season when any particular variety ought to be taken; for this is influenced variously by circumstances connected with soil, climate, and situation. The best general rule is, to gather when the fruit-stalk separates easily from the spur, on the fruit being raised by the hand from its natural or pendulous position. There are scarcely any exceptions to this rule, unless as regards a few of the summer and early autumn varieties, in which the flavour is improved by gathering a little earlier than is indicated by the above criterion.

The treatment of the fruit after gathering is by no means uniform; some lay it directly on the shelves of the fruit-room, or wherever else it is intended to remain till fit for use; others cause it to undergo a process of fermentation, called sweating, by throwing it in a heap, and covering it with some dry substance, generally straw; in some instances even blankets have been used for this purpose. After it has perspired for ten days or a fortnight, it is spread out at a time when the air is dry, in order to expedite the evaporation of the moisture. All unsound specimens, or even such as are suspected of being so, are then separated. In the case of particularly valuable sorts, it has been recommended to wipe off the moisture with flannel; but this proceeding, for reasons hereafter to be explained, is not advisable.

With regard to the final storing up, as it has been proved by experience that certain methods successfully practised by some, have turned out a failure when attempted by others, and as these fruits are extensively cultivated by persons variously circumstanced, some of whom are compelled by necessity to practise perhaps not the very best mode, but the best they can command, it will be proper to detail the various methods that have hitherto been tried, in order that such as are most deserving of recommendation may be pointed out, as well as those which ought to be avoided in every possible case.

The following are the different modes in which apples and pears have been deposited for winter use:—1. In single layers on the bare shelves of a fruit-room. 2. In the same manner, but covered with light canvas, which must be dried occasionally, as it absorbs the evaporation. 3. In close drawers; one layer, or several layers in depth. 4. In dry casks without any interposing material; a few weeks after they are first put in they require to be carefully picked over, the casks made perfectly dry and re-filled, the head closely fitted, and the fruit on no account disturbed until unpacked for use. 5. In boxes, casks, large garden pots, or jars, with pure and dry sand interposed between the layers of fruit. 6. In jars in which no sand or other substance is allowed to come in contact with the fruit, the mouths of the jars being covered with a piece of slate, and the whole plunged in a quantity of dry sand, so as to be several inches from the free atmosphere. The sand being a slow conductor of caloric, the sudden changes of temperature and their powerful effects in causing the decay of fruits are avoided. 7. In heaps in a dry airy loft, a slight covering of straw being given to protect them from frost. 8. In baskets lined with straw. 9. In close cellars excluded from the light, which is in all cases injurious. 10. In dark but airy vaults. 11. On a small scale, under a bell-glass cemented down air-tight; this must not be done on wood the least resinous, for even the white deal, which, when made into open shelves, communicates none of its flavour to the fruit, yet when supporting a close bell-glass, strongly taints whatever fruit is placed in it, by the confined and accumulating exhalation. 12. Buried in a box placed on four bricks, under another box inverted, in an excavation so deep that the upper portion of the fruit may be 1½ or 2 feet below the surface of the earth. 13. In threshed grain, or in corn stacks. 14. Reposing on wheat straw, with or without a covering of the same. 15. In chaff of wheat or oats. 16. In flax-seed chaff. 17. In powdered charcoal; this, if it cannot prevent, will in no degree contribute to decay, either internally or externally. It is the substance in which the imported Newtown pippins are frequently packed, and they would arrive much sounder than they do were it not for the bruises they evidently appear to have received previous to exportation. 18. In dried fern leaves.

Amongst so great a variety of modes, it is obviously of considerable importance to ascertain not only which are the best, but which experience has proved to be the worst. This inquiry is most advantageously pursued by settling in the first instance what the circumstances are that have been universally found detrimental to the preservation of fruits. As was remarked when mentioning the sixth mode, atmospheric changes have very great, if not the most powerful influences; firstly, as regards their caloric effects, and secondly, their hygrometrical. In the former respect, the expansion and condensation occasioned by the rise and fall of temperature must work a change in the state of the juices, doubtless often at variance with the gradual chemical change which these juices naturally undergo; hence, those fruits that are most exposed to vicissitudes of temperature are found to be most apt to fail in attaining their full sugary mellow perfection. Again, when warm weather suddenly succeeds cold, the air in the room is of a higher temperature than the fruit, until such time as the latter acquire from the former an equality of temperature; and until such time as this takes place, the fruit, from its coldness, acts as a condenser of the vapour existing in the warmer atmosphere by which it is surrounded, and the surface consequently becomes covered with a great deposition of moisture, as will be the case with a glass filled with water colder than the atmosphere of a room into which it is brought. The more smooth and glossy the variety of apple or pear, the greater is the condensation on its surface. Russeted apples and pears exhibit the least effects in this way, their rough dry coat being in less immediate contact with the cold juices of the fruit.

From the above it is sufficiently evident that variations in the state of the atmosphere, as regards its temperature, have injurious effects by the expansion and condensation of the juices, and by the deposition of moisture on the surface, partly owing to atmospheric humidity, but chiefly to the circumstance of the latter being condensed upon the fruit, as above explained. This deposition of moisture tends to decompose the skin, and to render it less efficacious as a protector. It therefore follows, that where fruit is not kept closely packed, it should be exposed to as little change of temperature as possible, and should also be preserved from the full effects of an atmosphere saturated with moisture. If a circulation of air could be secured of a uniform temperature and dryness, or nearly so, there is no doubt as to the superiority of flavour which the fruit would acquire. The watery particles would exhale, and at the same time shrivelling would not take place to any great extent, for this chiefly occurs in consequence of expansion and contraction, and alternate moisture and dryness of the surface, the results of irregularities in the state of the atmosphere. It may be here observed, that wiping the fruit is injurious. The skins of fruits are more or less covered with a secretion, technically called the *bloom*, which every one will have observed on grapes and plums, on both of which it is very conspicuous, and although less so on apples and pears, yet it does exist on them, and its use is to protect, in a great measure, the skin from the effects of moisture. Some fruit-growers are so well aware of this that they will not even handle their most choice wall-pears in gathering, except by the stalk.

Light is found to be injurious; all agree that fruit keeps best in total darkness. This arises from a specific stimulus being exercised upon the vegetable tissue by this agent. If a leaf, a green branch, or such a green surface as that of an apple or pear be exposed to light, even in the most diffused state, evaporation takes place; but as soon as the stimulus of light is withdrawn, evaporation ceases. Speaking of plants in general, evaporation from the green parts takes place all day long and ceases at night.

The preceding observations will explain the reason why a fruit room is best in a dry situation, on the north side of a wall or other building where the sun's heat will not readily disturb the temperature. The roof should be double, and the walls hollow; the windows small. There should be a full command of ventilation; but the room should also be capable of being entirely shut up.

Ventilation should be used only when the air, owing to the exhalations from the fruit, is not perfectly sweet; when this is not the case, air must be admitted in whatever condition it may happen to be; but it would be most desirable to admit air copiously *only when it is of an equal temperature with that of the interior of the room.* The latter should be in two or three compartments, in order to keep the late sorts entirely free from the contaminating effects of exhalations of fruit in a fully ripe state.

These being the conditions under which the ripening, decay, and preservation of apples and pears always take place, the reader will have no difficulty in judging of the relative advantages of the 18 methods already named. It is obvious that Nos. 1, 2, 3, 4, 5, 6, 7, are plans in which the circumstances essential to the preservation of fruit are nearly completely complied with. Nos. 8, 11, 14, 15, and 16, are bad, either because of the liability of the material in which they are packed to decomposition, by which the fruit acquires a tainted musty taste, or because they can only be applied on a very small scale. Nos. 9 and 12 are chiefly objectionable because, owing to the almost total absence of evaporation, the fruit, although well preserved and plump, is apt to be watery and tasteless. No. 17 is a troublesome and dirty practice; Nos. 13 and 18 are excellent when opportunity occurs of practising them; but No. 10, in dark but airy vaults, is undoubtedly that which most completely complies with the conditions necessary for preservation, and is much the best. We have known apples, that are usually decayed in February, preserved till Midsummer in this manner, in all their freshness and colour, and nearly all their flavour.

With regard to nuts and walnuts, the only precaution that it is necessary to take for their preservation is to maintain the air in which they are placed in a constant state of moisture. Burying in the earth, placing in a damp cellar, mixing with damp sand, and many such plans have been recommended; but they are all objectionable, either because they keep the fruit too moist, or do not offer any impediment to its becoming mouldy. We believe the best of all plans is to pack them in glazed earthen jars, throwing a small quantity of salt on the last layer before the jar is closed.

Apples and pears dried in ovens may be preserved for years. Bosc states that he has tried the latter, after three years' preservation, and found them still good; but they are best during the first year. They are placed in the oven after the bread is drawn. The process is repeated a second, third, or fourth time, according as the size or nature of the fruit may require. The heat must not be so great as to scorch, nor must the fruit be dried to hardness. When properly done, they are kept in a dry place. Another method, chiefly practised on the rousselets, and of these the rousselet de Rheims is the best for the purpose, is to gather the fruit a little before maturity; after being half boiled in a small quantity of water, they are peeled and drained. They are then placed in the oven, and heated to a suitable degree, for twelve hours. They are then steeped in syrup, to which have been added brandy, cinnamon, and cloves. They are again returned to the oven, which is heated to a less degree than at first: this operation is thrice repeated.

The flattened dried apples, called *beaufins*, so abundant in the London shops, are, as stated above, prepared in Norfolk, from a variety of apple called the Norfolk beaufin: it has a thick skin, which resists, without bursting, the heavy pressure to which the apples are subjected in the oven, during the slow and lengthened process of drying.

FRUIT-TRADE. This trade, as far as printed returns can show, is necessarily confined to foreign produce. Almost all the fruit grown at home is consumed at home. Our orchards and market fruit-gardens, however large, yield no surplus produce for us to sell to the foreigner; nor, indeed, could we sell it at a price that would yield an adequate profit after defraying the cost of carriage. Nor have we any means of knowing how much fruit is grown and eaten in England; the orchard-keepers and fruit-growers are not required to render to any one an account of the amount of their trade. Occasionally attempts are made to estimate these quantities. Some years ago, Mr. H. Mayhew, in the 'Morning Chronicle,' gave a tabulation which professed to be an account of all the fruit sold at Covent Garden Market in one year. Mr. Braithwaite Poole, goods'-manager on the greatest of our railways, presented an estimate of the quantity of fruit sold in all the markets of the metropolis in 1850, comprising such items as 17,000 tons of apples, 9000 tons of pears, 7000 tons of gooseberries, 4500 tons of plums, 4000 tons of currants, 1000 tons of damsons, 900 tons of cherries, 700 tons of strawberries, 230 tons of filberts, 230 tons of hazel-nuts, 50 tons of mulberries, and so forth. In so far are these estimates are reliable, they give a curious insight into the vast dealings and consumption of the metropolis; but they do not afford safe data for any inferences concerning the United Kingdom at large.

We will select 1856 as a year to illustrate the extent of the foreign fruit-trade; not because it was the latest available, but because it affords a pretty fair average of recent years. The imports of foreign fruits, in kinds and quantities, in the above-mentioned year, were :—

Almonds, sweet	34,000 cwts.
„ bitter	9,000 „
Apples, raw	530,000 bushels
„ dried	2,000 „
Currants, dried	350,000 cwts.
Figs, dried	44,000 „
Grapes	12,000 bushels
Chestnuts	67,000 „
Cocoa nuts	1,880,000 No.
Hazel nuts	218,000 bushels
Walnuts	56,000 „
Oranges and lemons	690,000 „
Pears	22,000 „
Plums	3,500 cwts.

Prunes	17,000 cwts.
Raisins	270,000 ,,
Tamarinds	1,400,000 lbs.
Various	97,000 bushels

Some of these were exported to other countries; the home consumption did not quite reach the above quantities.

FRUSTUM, a portion cut off from any solid figure. The term is most frequently applied in the case of the cone, and conoidal surfaces of revolution. By " frustum of a cone " is meant any part cut off from a cone which does not contain the vertex. This distinction is drawn because any part of a cone which contains the vertex is another cone.

FUCUSAMIDE ($C_{20}H_{12}N_2O_6$). An organic compound much resembling furfuramide, with which it is isomeric; obtained by the action of ammonia upon *fucusol.*

FUCUSINE ($C_{20}H_{12}N_2O_6$). An alkaloid isomeric with furfurine, obtained by boiling *fucusamide* with caustic potash or soda.

FUCUSOL ($C_{10}H_4O_4$). An organic substance isomeric with *furfurol*, obtained by distilling marine algæ with dilute sulphuric acid.

FUEL is any combustible matter employed for the purpose of creating and maintaining heat. In the early ages of the world, wood must have constituted, as indeed in many countries it does to this day, the principal fuel employed. Wood consists chiefly of three elements, —carbon, hydrogen, and oxygen. The two former are both of them highly combustible, hydrogen being especially so, and giving rise to the flame with which wood is well known to burn. When the smoke occasioned by the combustion of wood is found inconvenient, or when the fuel is required to last for a longer period in a given bulk, then charcoal is employed, which is merely wood that has undergone imperfect combustion, so as to expel its hydrogen and oxygen, and to leave the greater part of the carbon.

Another kind of fuel, which doubtless was early in use on account of the facility with which it is obtained from its nearness to the surface, is *peat*, or, as it is sometimes called, *turf*. This is a congeries of vegetable matter, in which the remains of organisation are more or less visible. Peat is the common fuel of a large part of Wales and Scotland, and of many districts of England, where coal is not readily procured.

In this country, however, coal furnishes the great supply of fuel, and its various kinds are employed in different ways and for different purposes, according to its nature and that of the substance to be acted on by its agency. When coal, by a process analogous to that by which charcoal is procured from wood, is freed from its more volatile constituents,—hydrogen, oxygen, and nitrogen,—it is converted into coke. It then burns with but little flame and no smoke, and is used for giving an intense degree of heat in the reduction of most metallic ores, especially those of iron. In some cases a mixture of coke and charcoal is very advantageously employed, especially in assaying in the small way. The mixture gives out a great degree of heat while burning, and being more combustible than coke alone, small furnaces, in which the draught is less powerful than in larger ones, are particularly adapted for its use; and though it consumes faster than coke, it lasts longer, gives a greater heat, and is more economical than charcoal alone.

In some countries, even the dried excrement of animals is used as fuel; and from the use of camels' dung the formation of sal ammoniac was derived in Egypt; this salt subliming from the excrement during its combustion.

In small chemical operations, as for the blow-pipe, tallow or wax candles are frequently employed; and in lamps, oil, spirit of wine, or methylated spirit are employed, and at the present time coal gas is almost universally used, either for the purpose of boiling or evaporating small quantities of fluids, or dissolving various bodies in different menstrua.

During the combustion of different kinds of fuel, the products vary: thus, when wood, coal, wax, tallow, oil, alcohol, or coal gas is employed, the principal products are carbonic acid gas and water; when charcoal is used, carbonic acid is almost the only volatile substance formed, for the hydrogen which the wood contained is expelled by the process of charring.

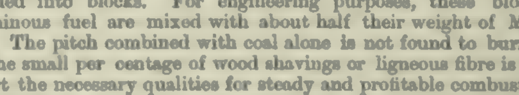
The sources of ordinary fuel will be found sufficiently described under CHARCOAL, COAL, COKE, GAS-LIGHTING, &c. A few words may, however, usefully be said concerning some of the kinds of *artificial* fuel introduced within the last few years. Oram's patent fuel was planned with a view to make use of the small coal which is so extensively left to waste at the mouths of the pits; this coal to be mixed with earthy substances, such as sand, marl, clay, or alluvial deposit; or with some bituminous substance, such as mineral tar, coal tar, gas tar, pitch, resin, or asphaltum; or with saw dust, coke dust, or breese. In short, this was one of those vague patents which defeat their own purpose by the wideness of their grasp. Mr. C. W. Williams, managing director of the Dublin Steam Packet Company, has patented three or four inventions for artificial fuel in which peat shall be one of the ingredients. The peat, after being partially dried, is pressed with great force, to expel the remaining moisture; and it is then mixed with some bituminous substance. By different modes of treatment Mr. Williams produced a very dense brown combustible solid, a charcoal twice as compact as hard wood charcoal, an artificial coal, and an artificial coke. Mr. Bethell's patent fuel consists of small coke and dust from gas works, or breese; the breese is mixed with coal tar and put into a coke oven, where it is burned into good coke. If burned in open heaps, it would also produce coke, but of inferior quality. Seventy-five per cent. of breese is found to be a good proportion with twenty-five of pitch or coal-tar. Instead of coke, bricks of artificial fuel are sometimes produced by casting the mixture into iron moulds, and baking. Mr. Warlich's patent fuel is employed rather extensively; it is made of some such mixture of materials as Bethell's, but with especial attention to its fitness for use in marine engine furnaces, locomotive furnaces, and stationary engine furnaces. In the investigations made by commissioners employed by the Admiralty, into the qualities of various kinds of fuel adapted for the engines of H. M.'s steam navy, Warlich's, and some other kinds of artificial fuel, were found to be favourable, when alternating under certain conditions with good coal. Dr. Arnott, in a Report on the Paris Exhibition of 1855, said :—" A very important object exhibited was a prepared fuel called the *Charbon de Paris.* The manufacturer takes fragments or dust of bituminous coal, or of anthracite, charcoal, or coke, and mixing these in certain proportions with coal-tar, &c. makes a soft mass, which, by moulding, he shapes into cylindrical pieces about four inches long by one and a quarter in diameter; and he afterwards hardens them by heat, these being very like charcoal, free from slate, and giving intense heat. There are now many makers of such fuel, seeming to believe the excellence of their product to depend chiefly on the proportions of the ingredients, and attributing too little to the uniform size and shape of the pieces, which allow that rightly proportioned approach of air to them on which perfect combustion so much depends. There were in the Exhibition many specimens, both continental and English, of artificial coke or fuel of kindred composition, in much larger masses. An obvious advantage of such over common coal is that the lumps, when put together, occupy less space than an equal weight of irregularly-broken common coal, and therefore can be stowed more advantageously in ships. And in the composition, there may be of bitumen or pitchy matter just what aids the steady combustion without causing smoke; having, therefore, neither the excess nor the deficiency found in many natural coals."

Nearly all these kinds of artificial fuel consist of small coal, small coke, ashes, and bituminous substances, combined in various numbers and various degrees, and subjected to different modes of manipulation. There is one exception, however, in the case of the Trinidad pitch fuel, with which no kind of coal or coke is mixed. There is a great pitch-lake on that island; and a company has been formed for converting the pitch into fuel, by mixing it with wood shavings. The pitch, thoroughly wetted, is mixed with about eight per cent of shavings, and is then moulded into blocks. For engineering purposes, these blocks of bituminous fuel are mixed with about half their weight of Merthyr coal. The pitch combined with coal alone is not found to burn well; but the small per centage of wood shavings or ligneous fibre is said to impart the necessary qualities for steady and profitable combustion.

FUGUE, in music, is a composition in which a subject, or brief air, passes successively and alternately from one part to another, according to certain rules of harmony and modulation. Such is Rousseau's definition, which would have been more complete if he had added that the Fugue is also formed after rules peculiar to itself. The term seems to have originated about the middle of the 15th century, and is commonly supposed to be derived from the Latin word *fuga* (flight), because the theme, or point, flies from part to part; but this etymology is by no means satisfactory, though we certainly have no better to offer.

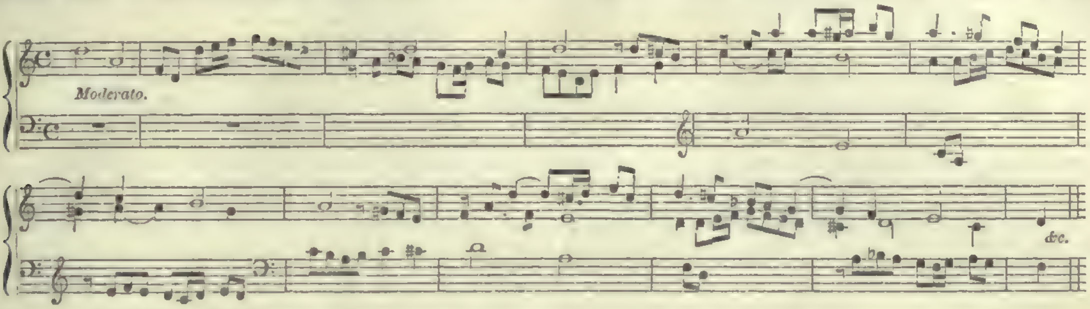
Writers on music enumerate many kinds of Fugue, the chief of which are, the *Strict Fugue*, the *Free Fugue*, the *Double Fugue*, and the *Inverted Fugue*; to which we shall add that species—for it decidedly belongs to the Fugue genus—called *Imitation.*

" In a Strict Fugue," says Dr. Crotch (' Elements of Composition '), " the subject is given out by one of the parts, then the answer is made by another; and afterwards the subject is repeated by a third part, and, if the fugue consist of four parts, the answer is again made by the fourth part: after which the composer may use either the subject or the answer, or small portions of them, in any key that he pleases, or even on different notes of the key." In this severe kind of composition, when the subject, or leader, or point, or *dux*, or by whatever name the theme may be designated, is comprised between the tonic and the dominant the answer (or *Comes*) must be given in the notes contained between the dominant and the octave. Example:



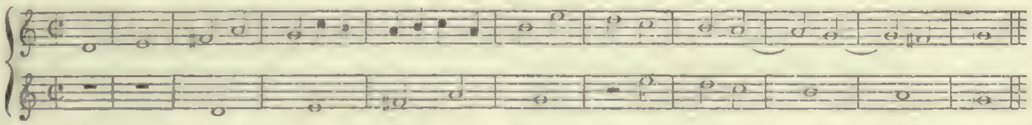
The chorus, ' He trusted in God,' in the ' Messiah,' is a fine specimen of this sort of fugue, to which we refer the reader; for few persons are without that sublime oratorio in some form.

In the Free Fugue much more latitude is allowed the composer; he is not so restrained by the subject, but may introduce what Albrechtsberger terms episodes—passages not closely related to the theme, though they should never be very foreign to it. The overture to the 'Zauberflöte' affords a splendid example of this species. The Double Fugue consists of two or more subjects moving together, and dispersed among the different parts. Dom. Scarlatti's in D minor is a double fugue which has no superior of its kind. The first few bars of this will more clearly explain than words can do the nature of so elaborate a species of composition.



Fugues of more than two subjects are classed, not very correctly, among double fugues; they are, however, rare, for which reason perhaps they have never received a distinguishing name. Of these the fugue of four subjects in the finale to Mozart's grand symphony in C, and that of the same description in Handel's *Alexander's Feast*, the chorus 'Let Old Timotheus yield the prize,' are master-pieces of their kind. All of this species must be considered as free fugues. The term Fugue by Inversion requires little explanation. In this the theme is inverted, as the name implies, but the effect arising out of such contrivance is appreciable only by those who know its difficulty, and estimate its merit by the quantity of labour it has cost. In the Fugue by Augmentation, the notes of the answer are doubled in length. In the Fugue by Diminution, exactly the reverse takes place. There are other kinds of Fugue, but they are now almost forgotten, and it would be useless to revive their names.

Imitation is a species of fugue, and by theorists is generally treated on previously to and as the precursor of the latter. As the word indicates in this kind of composition, the theme is more or less imitated in the different parts. It is not required, says Fux (*Gradus ad Parnassum*), that every note should be imitated, but only some part of the subject; and Imitation is rather to take place in the middle than in the commencement of a composition. It may be made in any of the intervals, and in fact is governed by scarcely any rule. The learned contrapuntist just named gives the following as an example of Imitation in the Unison :—



The effect of technical imitation in music is unquestionably great; it is felt by all who have the slightest skill in the art, therefore employed by all great composers of every school, ancient and modern. Canon, which is sometimes called a perpetual fugue, may perhaps be admitted, though cautiously, as part of a course of professional study, but should rarely, if ever, be allowed to pass the boundaries of the school. [CANON.] Fugue, but not of the pedantic or fantastic kind, should be an object of serious attention with those who are ambitious of becoming great composers, though in its severe form it ought to be almost confined to cathedral music and to the oratorio, and is admissible there only when introduced with great discretion, and guided by the hand of an experienced sensible master. But without that which is here to be understood by the term imitation—or the recurrence, in some shape, of the chief subject—music in parts, of even a very simple kind, loses one of its greatest beauties. Let it be used however with a view solely to effect: if resorted to for the mistaken purpose of displaying what a young or a dull composer may call his learning, imitation will prove to be nothing better than mere plodding, and capable of exciting no emotion except that which is the very reverse of pleasing.

FULCRUM. [LEVER.]

FULGURITE. [LIGHTNING; and FULGURITE in NAT. HIST. DIV.]

FULLING. [WOOLLEN MANUFACTURES.]

FULMINATING MERCURY (HgO_2, $C_4N_2O_2$). The compound of *Fulminic Acid* with mercury. It is prepared by dissolving 1 part of mercury in 12 of nitric acid, sp. gr. 1·36, and then adding 11 parts of alcohol, sp. gr. ·850. If a gentle heat be now applied by means of a water-bath violent reaction ensues, metallic mercury is deposited, and minute crystalline grains of fulminate of mercury separate, these must be washed with cold water and dried at 100° Fahr. They explode violently by percussion or heat, or by contact with sulphuric acid. The preparation even of small quantities of fulminating mercury is attended with considerable danger, and ought not to be attempted by any one unacquainted with chemical manipulation. Mixed with six times its weight of nitre it is used for priming percussion caps.

FULMINATING SILVER ($2AgO$, $C_4N_2O_2$). This salt of fulminic acid is obtained by dissolving 1 grain of silver in 20 grains of nitric acid diluted with 50 grains of alcohol. The remaining processes are similar to those used for the preparation of fulminating mercury, than which it is still more dangerously explosive. [FULMINATING MERCURY.]

FULMINIC ACID ($2HO$, $N_2C_4O_2$). An acid which is isomeric with cyanic acid [CYANIC ACID], that is, composed of the same elements in the same proportions, and they appear to have similar saturating powers. Fulminic acid has not yet been isolated, but it exists in the detonating mercury and silver discovered by Mr. Howard. These fulminates, as shown under the respective metals, are prepared by the simultaneous action of nitric acid and alcohol upon them: in this operation the metals are oxidized, and such portions of the carbon of the alcohol, and nitrogen and oxygen of the decomposed nitric acid combine, as to form the fulminic acid. Fulminic acid may be separated from the oxides of silver and of mercury, and combined with other bases, as with potash, and it still retains its power of forming detonating compounds. [CYANOGEN.]

FULMINURIC ACID (HO, $C_6H_2N_3O_5$), *Isocyanuric Acid.* A recently discovered acid isomeric with cyanuric acid. The salts of this acid are obtained by boiling the different fulminates with a solution of a soluble chloride. They crystallise generally with facility, and explode feebly on the sudden application of heat. [CYANOGEN.]

FUMARIC ACID. *Boletic acid.* This acid was first procured by Braconnot from the *boletus pseudo-igniarius* by the following process: the expressed juice is to be evaporated to the consistence of a syrup, and then treated with alcohol, which leaves a white matter; this is to be washed with alcohol, then dissolved in water, and precipitated with a solution of nitrate of lead; the precipitate diffused through water is to be decomposed by sulphuretted hydrogen gas; by evaporating the remaining solution there are obtained impure crystals of fumaric acid, and a very acid mother-water, composed of fungic and phosphoric acids. The crystals of fumaric acid are redissolved in alcohol, which leaves a calcareous salt, and by evaporating the solution purer crystals of fumaric acid are procured. Fumaric acid may also be obtained by submitting malic acid to heat, and it is also present in Iceland moss, fumitory and other vegetables.

Fumaric acid is colourless, crystallises in four-sided prisms; its taste is acid, like that of bitartrate of potash; it reddens litmus, does not alter by exposure to the air; is gritty, like sand, between the teeth. It is soluble in 180 parts of water at 68°, and in 45 parts of alcohol. By heat the greater part of it is sublimed either in prismatic crystals or in fine powder; but towards the end of the operation some empyreumatic oil is formed, and there is a strong smell of acetic acid. It has the peculiar property of precipitating the peroxide of iron from solutions, but not the protoxide.

This acid forms salts with the alkalies and other bases; they are called fumarates. They are not important compounds, none of them being applied to any use. (Berzelius, 'Traité de Chimie,' tom. 5, p. 102.)

FUMARAMIDE ($C_8H_6N_2O_4$). When the *fumarate* of oxide of ethyl, which is a heavy oily liquid, is acted on by *aqua ammoniæ*, it forms a white insoluble powder, which is *fumaramide*, and possesses all the characters of a compound amide.

FUMARIMIDE ($C_8H_3NO_4$?). A reddish amorphous powder, formed by exposing bimalate of ammonia to a heat of about 400° Fahr. Heated for several hours with hydrochloric acid, it yields aspartic acid.

$$C_8H_3NO_4 + 4HO = \underbrace{C_8H_7NO_8}_{\text{Aspartic acid.}}$$

FUMIGATION is the application of the vapour or fumes from metallic or other preparations to the body, with the intention of healing either generally, or particular parts. The vapours of hot vinegar, burning sulphur, and of aromatic vegetable matters, have been long used to counteract unpleasant or unwholesome smells: this is effected chiefly by the formation of such as are stronger. The most important kind of fumigation is that which consists in the employment of such vapours or gases as do not merely destroy unhealthy odours by exciting such as are more powerful, but which by their chemical action convert dangerous miasmata into innocuous matter.

The fumigation of the first kind, that which is intended to produce a healing effect, is now much less employed than formerly; still, however, the bisulphide of mercury is occasionally used in vapour, as what is termed a mercurial fumigation, in certain forms of syphilis. The use of vinegar, of aromatic pastilles, and even the smoke of burning brown paper, which constitute the second kind of fumigation, does not require any particular notice; their operation can hardly be regarded as any other than that of substituting one smell for another. In the last kind of fumigation three substances have been chiefly employed, and in the gaseous state: first the vapour of burning sulphur, or sulphurous acid gas, hydrochloric acid gas, nitrous acid gas, and chlorine gas; all but the last of these, or at any rate the first and second named, appear to have been first used and recommended by Dr. James Johnstone, of Worcester, about the year 1758; in 1773 Guyton de Morveau also mentioned the application of hydrochloric and nitrous acid gases, and in 1802 their use was still further extended by Dr. J. C. Smith, who received a public remuneration as the discoverer, which he certainly was not.

Chlorine gas, which is undoubtedly preferable to any disinfectant, was first recommended by Dr. Rollo, who published a work on diabetes in 1797; he liberated the gas by the usual method of mixing sulphuric acid, binoxide of manganese, and common salt. When it is desirable to produce a great effect in a short time, this is still unquestionably the best mode of proceeding.

We shall give an abstract of the mode adopted by Mr. Faraday in fumigating the Penitentiary at Milbank in 1825. ('Quarterly Journal,' vol. xviii., p. 92.)

The space requiring fumigation amounted to nearly 2,000,000 cubic feet; and the surface of the walls, floors, ceilings, &c., was about 1,200,000 square feet. This surface was principally stone and brick, most of which had been lime-washed. A quantity of salt reduced to powder was mixed with an equal weight of binoxide of manganese, and upon this mixture were poured two parts of sulphuric acid, previously diluted with one part of water, and cold. The acid and water were mixed in a wooden tub, the water being first put in, and it being more convenient to measure than to weigh the water and acid, ten measures of water and nine of acid were used; half the acid was first used, and when the mixture had cooled the remainder was added.

Into common red earthen pans, each capable of holding about a gallon, were put 3½ lbs. of the mixed salt and manganese, and there was then added such a measure of the diluted acid as weighed 4½ lbs.; the mixture was well stirred and then left to itself, and all apertures were well stopped. The action did not commence immediately, so that there was sufficient time for the operator to go from pan to pan without inconvenience. On entering a gallery 150 feet in length, a few minutes after the mixture had been made, the general diffusion of chlorine was sufficiently evident; in half an hour it was often almost impossible to enter, and frequently on looking along the gallery the yellow tint of the atmosphere could easily be perceived. Up to the fifth day the colour of the chlorine could generally be observed in the building; after the sixth day the pans were removed, though sometimes with difficulty, and the gallery thus fumigated had its windows and doors thrown open. The charge contained in each pan was estimated to yield about 5½ cubic feet of chlorine gas; in fumigating a space of 2,000,000 cubic feet, about 700 lbs. of common salt and the same of binoxide of manganese were employed: and it will appear by a slight calculation, that about 1710 cubic feet of chlorine were employed to disinfect this space. In common cases, Mr. Faraday conceives that about one-half to one-fourth of this quantity of chlorine would be sufficient.

When any cause for fumigation is continually recurring, and in some cases almost imperceptibly so, the chloride of lime or soda, and especially of the former, has been within a few years successfully employed by M. Labarraque; the exact nature of these compounds is still under discussion, but the chloride of lime is a substance well known and extensively employed under the name of bleaching-powder.

We shall relate a few experiments performed by M. Gualtier de Claubry, illustrative of the mode in which these substances produce their effects. A solution of chloride of lime exposed to the air for about two months, ceased to act upon litmus, contained no chlorine, but a precipitate was formed in it which consisted entirely of carbonate of lime, without any admixture of chlorine; it was therefore evident that the carbonic acid of the atmosphere had decomposed the chloride of lime, evolved the chlorine, and precipitated the lime. That this was the case was proved by passing atmospheric air through a solution of potash, before it was made to traverse one of chloride of lime; in this case the potash separated the carbonic acid, so that no chlorine was evolved from the solution of chloride of lime, nor was any precipitate formed in it; in fact no change whatever occurred. That it was the carbonic acid which produced this effect, was further proved by passing a current of this gas into a solution of chloride of lime; by this it lost its bleaching power, the whole of the chlorine was expelled, and all the lime converted into carbonate.

In order to show the manner in which these compounds of chlorine and lime, and of chlorine and soda, act on putrid miasmata floating in the air, some further experiments were made in the following manner: Air was passed through blood which had been left to putrefy for eight days; being then passed through a solution of the chloride of lime, carbonate of lime was deposited, and the air was rendered inodorous and completely purified. In a second similar experiment the fetid air was passed through a saturated solution of potash before it arrived at the solution of chloride of lime; the latter had then no effect upon it, and the air retained its insupportable odour; this happened evidently because the carbonic acid, which would otherwise have evolved chlorine to have acted upon the putrid matter, was absorbed by the potash. Another experiment was made with air left for twenty-four hours over putrescent blood; the portion of it which was passed directly through the chloride was perfectly purified, but when previously freed from carbonic acid the chloride had no effect upon it.

These experiments sufficiently prove that the carbonic acid in the air, arising from the various sources of respiration, combustion, and the decomposition of animal and vegetable matter, liberates the chlorine from its combination with lime or soda; and as this action is slow, the chlorine, though scarcely susceptible of affecting the animal economy, readily decomposes putrid miasmata. It is therefore true fumigation by chlorine, only it is less violent than that effected by the rapid evolution of the gas, and it continues for a longer time.

It is to be observed that chloride of lime is used in solution, and is obtained by dissolving one part of bleaching powder in about 100 times its weight of water, and allowing the solution to become clear. This is to be exposed to infected air, or in rooms which have any unpleasant odour, in flat vessels, in order that a sufficient surface may be acted upon. If it should be required, the operation may be quickened by the addition of a little vinegar, or of muriatic acid largely diluted. In some cases, where the disagreeable smell is extremely strong, and where it would be difficult to expose a solution to slow action, it may be thrown into the place, or the powder may be used, the action of which would be more gradual and effectual. Chloride of soda is prepared only in solution; the process is given in the last edition of the 'London Pharmacopœia:' it is however less easily obtained than the chloride of lime, is more expensive, and not in any respect preferable; the solution is then called liquor sodæ chlorinatæ.

FUNCTION, ARBITRARY. In the integration of partial differential equations, arbitrary functions are introduced, that is, functions which may be of any form whatsoever. Thus, in the problem of the vibrations of a thin column of air, which leads to an equation of the form

$$\frac{d^2z}{dx^2} = a^2\frac{d^2z}{dy^2}$$

the complete solution of the equation is

$$z = \phi\,(y + ax) + \psi\,(y - ax)$$

when ϕ and ψ stand for any functions whatever. The determination of these arbitrary functions must depend upon the data of the problem. Thus, if it were required so to determine ϕ and ψ as that z should become x when y is x, and x^2 when y is bx: we have then to determine the forms of ϕ and ψ from the two equations

$$\phi\,(x + ax) + \psi\,(x - ax) = x$$
$$\phi\,(bx + ax) + \psi\,(bx - ax) = x^2$$

These two functional equations might be solved without much difficulty, and forms of ϕx and ψx found. Theoretically, the determination of the arbitrary functions, so as to satisfy given conditions, resolves itself into the solution of functional equations.

But when these questions were first considered, it was soon seen that the problems from which they are derived present very peculiar circumstances. For instance, when the problem is that of finding the manner in which a disturbance travels along a thin column of air, the preceding equation exists, where z represents the amount of compression or rarefaction which exists in the air at a distance y from a fixed origin at the end of the time x from the beginning of the motion. Now, in practice, there is no disturbance of the state of the air at the beginning of the motion, except in one small part of the column (as in a sound excited at one end of a cylindrical tube). Suppose, for example, that by introduction of external air, a certain amount of compression, c, is generated at the first moment ($x = 0$) throughout the portion of the tube which extends from $y = 0$ to $y = m$. When $x = 0$, z is $\phi y + \psi y$, and the conditions of the problem require that $\phi y + \psi y$ should be equal to c when y lies between 0 and m, and always equal to nothing when y is greater than m. Hence, $\phi y + \psi y$ must be a discontinuous function; so that in this simple problem mathematical methods are insufficient to express a solution, unless discontinuous functions can be admitted among the solutions of partial differential equations.

There was, at one time, a spirited discussion between Euler, D'Alembert, and Lagrange, as to whether discontinuous functions could properly be admitted among the solutions of differential equations. We cannot enter into the details of this discussion, but we shall state the manner in which the question has been settled.

The considerations in Curve give some approach to the notion that curves which are perfectly independent may be combined in one equation; and also that a continuous curve may be drawn, the arc of which runs as near as we please to two distinct branches of two independent curves. The power of expression given by means of definite integrals and periodic series [Integrals, Definite], puts this result in a stronger light. Suppose, for example, that an axis of x being taken, we want to express mathematically the ordinate y, in such manner that it shall be nothing from $x = -\infty$ to $x = 0$; that of a certain straight line from $x = 0$ to $x = a$; that of a certain circle from $x = a$ to $x = b$, and nothing again from $x = b$ to $x = \infty$. In other words, we ask whether a line which is both limited and discontinuous, being a part of a straight line and a part of a circle, can be put upon the same sort of footing as an algebraic curve; so that a definite equation $y = \phi x$ shall always give $y = 0$ when there is no ordinate, and shall give the proper value of y whenever there is an ordinate. The answer to this is, that such an expression for ϕx can be given, when the notation of the integral calculus is assumed. And more than this, a *continuous* curve can be found which fulfils all the conditions above noted, as nearly as we please. That is, m being a small quantity which we may name as small as wel please, it is possible to find a continuous curve, the ordinate of which shall never be so great as m from $x = -\infty$ to $x = 0$, shall never differ by so much as m from the ordinate of the straight line while x passes from 0 to a, nor from that of the circle while x passes from a to b, and finally, shall never be so great as m from $x = b$ to $x = \infty$. Having the power of making m as small as we please, we thus trace the expression, as it were, into its final discontinuous form when $m = 0$.

In this manner, it appears that every discontinuous function may be regarded as the limiting form of a continuous one; and the various modes in which this is established take away all idea of danger from admitting discontinuous functions among the solution of differential equations. This subject is well studied in its application to physics.

FUNCTIONS, CALCULUS OF. By the term *function of a quantity* is meant any algebraical expression, or other quantity expressed algebraically or not, which depends for its value upon the first. Thus the circumference of a circle is a function of the radius; the expression $(a^2-x^2)(b^2+y^2)$ is a function of a, b, x, and y. For the distinctive names of functions, see Transcendental and Algebraical.

All algebra is, in one sense, a calculus of functions; but the name is peculiarly appropriate, and always given, to that branch of investigation in which the *form* of a function is the thing sought, and not its value in any particular case, nor the conditions under which it may have a particular value. [Equations, Functional.] For instance, "What is that function of x which, being multiplied by the same function of y, shall give the same function of $x+y$?"—is a question of the calculus of functions.

Various isolated questions connected with this calculus have been treated, from the time of Newton downwards, particularly by Lagrange, Laplace, Monge, and Euler. But the direct solution of functional equations, or at least the first attempt to form general methods in the case of functions of a single variable, appears to have been made by Mr. Babbage and Sir J. Herschel (1810-1813). To the treatise entitled 'Examples of the Calculus of Differences,' by the latter, the former appended another, containing examples of the solutions of functional equations. This last, and the article 'Calculus of Functions,' in the 'Encyclopædia Metropolitana,' are the only formal treatises on the subject of which we know.

A function of x is denoted by ϕx, ψx, χx, fx, Fx, Φx, &c., &c., the first letter being a symbol of an operation to be performed. Thus, Ffx denotes that when the operation signified by f has been performed upon x, that signified by F is performed upon the result. When the same operation is repeated, the results may be denoted by fx, ffx, $fffx$, &c., which may be abbreviated into fx, f^2x, f^3x, &c. For different points of interest connected with the relations of functional forms, see Periodic; Inverse.

FUNCTIONS, THEORY OF, a name given by Lagrange to a view of the principles of the Differential Calculus, of which we have expressed our opinion in the article Differential Calculus. The works of Lagrange, in which its details are to be found, are 'Théorie des Fonctions Analytiques,' first edition, 1797, second edition, 1813; and 'Leçons sur le Calcul des Fonctions,' of which the first publication is vol. x. of the 'Leçons de l'Ecole Normale' (1801); the first separate edition was published in 1797, and the second was published in 1806.

Taking Lagrange's intention to have been the proof that algebra, as it existed in his time, was sufficient to demonstrate the principles of the Differential Calculus without the introduction of limits, we have only to remark that the end is completely attained. [Differential Calculus.] It is plain to any one acquainted with that calculus, that a demonstration of Taylor's Theorem being once attained, all the rest follows. We now proceed to look at the proof of this theorem given by Lagrange, with reference to absolute correctness or incorrectness.

Lagrange first attempts to prove that every function ϕx has this property, that $\phi(x+h)$ can be expanded in a series of the form

$$\phi(x+h) = \phi x + \mathrm{A}h + \mathrm{B}h^2 + \mathrm{C}h^3 + \ldots\ldots$$

He says, firstly, that no negative powers of h can enter the expansion, for if such were the case $\phi(x+0)$, instead of being ϕx, would be infinite. This is true as to any finite number of negative powers of h, but does not exclude an infinite series of negative powers. For instance,

$$\frac{1}{x+h} = \frac{1}{h} - \frac{x}{h^2} + \frac{x^2}{h^3} - \ldots.$$

when $h=0$, *all* the terms become infinite, but the first side of the equation is not infinite. Secondly, he assumes that there cannot be fractional powers of h, for if such were the case, there must be fractional powers in the original function ϕx, and if ϕx had m different values, and if $\mathrm{K}h^{\frac{p}{n}}$ were one of the terms of the development, the n values of this latter, combined with the m values of ϕx, would give mn different values to $\phi(x+h)$, instead of m. In answer to this it may be asked how is it known, *à priori*, that there must be a series of powers of h, *every* value of which is an expansion of $\phi(x+h)$? May it not possibly be true that there is an expression of the form

$$\phi(x+h) = \phi x + \mathrm{A}h^{\frac{m}{a}} + \mathrm{B}h^{\frac{n}{b}} + \ldots.$$

which is true under certain conditions, determining which of the values of the several terms are to be taken? Thirdly, he assumes that (having thus obtained a series, in which only whole powers of h are found) the supposition $h=0$ must reduce it to its first term; an assumption which can only be admitted of such a series as $\mathrm{M} + \mathrm{A}h + \mathrm{B}h^2 + \ldots.$ when it can be made convergent by giving sufficiently small values to h.

Having once proved or assumed that $\phi(x+h)$ can be expanded in a series of the form $\phi x + \mathrm{A}h + \mathrm{B}h^2 + \ldots$ the proof of Taylor's Theorem, given by Lagrange, does not differ from the common one. He calls A the derived function of ϕx, and denotes it by $\phi' x$: generally, if changing x into $x+h$ change P into $\mathrm{P} + \mathrm{P}'h + \ldots.$, P′ is the derived function of P. The derived function of $\phi' x$, denoted by $\phi'' x$, is called the second derived function of ϕx, and so on. By changing x into $x+k$, $\phi(x+h)$, or $\phi x + \mathrm{A}h + \mathrm{B}h^2 + \ldots$, becomes

$$(\phi x + \phi' x \,.\, k + \ldots) + (\mathrm{A} + \mathrm{A}'k + \ldots)h + (\mathrm{B} + \mathrm{B}'k + \ldots)h^2 + \ldots.$$

and by changing h into $h+k$, $\phi(x+h)$ becomes

$$\phi x + \mathrm{A}(h+k) + \mathrm{B}(h+k)^2 + \ldots.$$

These must be the same, since both represent $\phi(x+h+k)$: and by equating the terms which contain the first powers of k, we find

$$\phi' x + \mathrm{A}'h + \mathrm{B}'h^2 + \ldots = \mathrm{A} + 2\mathrm{B}h + \ldots.$$

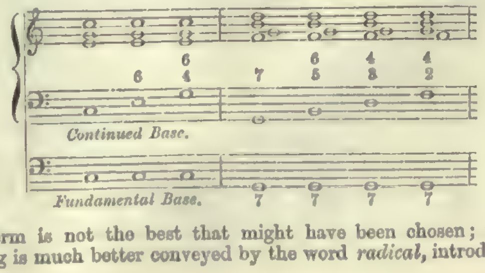
whence $\mathrm{A} = \phi' x$, $2\mathrm{B} = \mathrm{A}' = \phi'' x$, and so on. The reader will recognise in this process the proof frequently given by means of the preliminary lemma, that if

$$u = \phi(x+h), \quad \text{then } \frac{du}{dx} = \frac{du}{dh}.$$

The works of Lagrange on this subject, though defective in their fundamental positions, except upon the explanation given in Differential Calculus, yet abound in new and useful details, given with all the elegance for which his writings are distinguished: and the student will find them well worth his attention.

FUNDAMENTAL BASE, in music, is the lowest note of the Perfect Chord, or Triad, as the Germans call it, and of the chord of the 7th: hence it is the root of all real chords;—for chords not derived from either the perfect chord or that of the 7th, are considered as suspensions or retardations; or, to speak in unaffected language, the discordant notes of which they are composed are simply *appogiaturas*. [Chord.]

The following will show the two *Fundamental Chords*, and their inversions, with the continued [Continued Base], or ordinary base, and the *Fundamental Base*.



This term is not the best that might have been chosen; the same meaning is much better conveyed by the word *radical*, introduced, we believe, by Dr. Callcott. The *system* of the Fundamental Base, founded on harmonics, and a continual addition of thirds to the triad, is indebted for its origin to Rameau, the celebrated French composer [RAMEAU, in BIOG. DIV.], and was once almost universally received. D'Alembert wrote a book to explain and eulogise it, and Marpurg, a most distinguished theorist, adopted it in his 'Handbuch bey dem Generalbasse.' But though it may be rendered in some degree serviceable in the analysis of chords, it is in more than one respect erroneous, and the rules drawn from it by its author would cruelly fetter genius, were they allowed to exert any influence on the composition of music. Rameau's once vaunted system is now therefore entirely laid aside, even in the country that gave it birth.

FUNDS; FUNDING SYSTEM. [NATIONAL DEBT.]

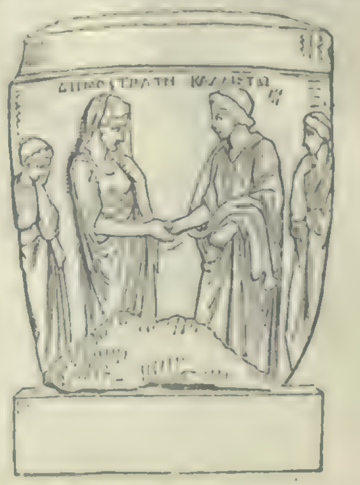
FUNERAL, the performance of the rites of sepulture or burial; generally supposed to be derived from the Latin *funis*, "a torch," because, at least in the Roman times, funerals were sometimes performed by torch-light. Others derive the word from *phónos* (φόνος), "slaughter," as designating death.

The Egyptians are among the earliest people of whose religious ceremonies we have authentic accounts, more particularly in what related to their dead. Upon this occasion the parents and friends of the deceased put on mourning habits, and abstained from gaiety and entertainments. The mourning lasted from forty to seventy days, during which time the body was embalmed, and, when the process was completed, placed in a sort of chest, which was afterwards preserved either in their houses or in the sepulchres of their ancestors. Before the dead were allowed to be deposited in a tomb, they underwent a solemn judgment, upon an unfavourable issue of which they were deprived of the rite of burial. The funeral was conducted with great ceremony. The embalmed body was conveyed on a kind of sledge drawn by cows or oxen, or placed in a boat and towed along the river. In front of the bier, a seated figure representing Anubis is often seen in Egyptian paintings. The sledge was preceded by hired female mourners, with their breasts uncovered, and their hair hanging loose down their backs. The relatives followed, and priests were in attendance to perform the necessary religious ceremonies; but, judging from the ancient paintings of funerals, the arrangements varied considerably with persons of different ranks and at different times. (See Rossellini, plates No. cxxvii., &c.; and Wilkinson.)

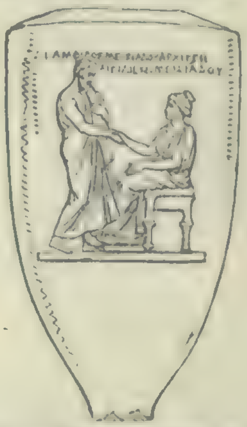
Among the ancient Jews it is clear that great regard was paid to a due performance of the rites of sepulture. (Gen. xxiii. 2-4; l. 7-13; 2 Chron. xxxii. 33; Amos v. 16; and the references to interment generally throughout the Scriptures.) In Egypt and Babylon the Jews seem to have placed the body in a coffin; but elsewhere, both in the earlier ages and in the time of our Saviour, it was customary to wrap the corpse in linen cloths and carry it quickly to the tomb. That they sometimes burnt the body is clear; but burial in a sepulchre was the more usual fashion. (See further, Jahn, 'Jewish Antiquities,' §§ 205–211, and the various commentators on the Bible. The circumstances attending the burial of the dead among the modern Jews are minutely detailed by D. Levi, in his 'Succinct Account' of their Rites and Ceremonies, pp. 162-170.)

In the religious creed both of the Greeks and Romans, sepulture was peculiarly an act of piety towards the dead, without which it was supposed the departed spirit could not reach a place of rest. To be deprived of the proper rites was considered the greatest misfortune (Homer, 'Od.,' v. 311, and xi. 66); and the abhorrence of certain crimes was strongly marked by the refusal of burial to criminals convicted of them. The funeral rites of the Greeks and Romans were in many respects similar, and among both nations the practice prevailed of burning the dead and collecting the ashes in urns. In the case of public funerals, according to Servius's 'Commentary on Virgil,' the deceased was kept seven or eight days, and every day washed with hot water, or sometimes with oil, that in case he were only in a slumber he might be waked; and at stated intervals, his friends, meeting, made a shout with the same view: this was called *conclamatio*. On the seventh day, if no signs of life appeared, he was dressed and placed on a couch in the vestibule, with the feet outwards, as if about to take his departure,—a piece of coin being placed in his mouth for the purpose of paying the fee of the ferryman in Hades. In the course of these seven days, an altar was raised near the bed-side, called *acerra*, on which the friends offered incense. The scene here described is frequently represented in ancient bas-reliefs: several such are in the British Museum. On the seventh day the last "conclamatio" ended, when the couch and body were carried to the *rostra*, where the nearest of kin pronounced the funeral oration, and afterwards to the funeral pile. In the case of persons of importance, the funeral procession was often very splendid. The cost of funerals of persons dying intestate was determined by an officer appointed for the purpose. The body having been consumed, the ashes were gathered, inclosed in an urn, and finally laid in the sepulchre or tomb. An apotheosis, or canonisation, was frequently part of the funeral ceremony of the emperor. A banquet was a part of the funeral ceremony among both the Greeks and Romans. Although the practice of cremation was general with both people, interment was always more or less resorted to. The practice of burning the dead eventually gave way before the spread of Christianity.

In the British Museum are numerous marble cinerary urns (or those which contained the ashes of the dead), both of Greek and Roman date, and others of painted earthenware, both Greek and Etruscan. There are also in the British Museum many solid funeral urns, which were merely commemorative of the deceased; as well as inscribed monumental tablets, and columns, or cippi. We give cuts of two of these Greek urns. The first, a fragment of a fine cinerary urn, is in the Elgin Saloon (No. 275). The young man and woman who are joining hands have their names inscribed above,—Demostrate and Kallisto. The second cut is from a solid funeral urn, 2 feet 3½ inches high, found in the ruins of the Corinthian portico in the bazaar at Athens. It is now in the Elgin Saloon (No. 192). From the inscription we learn that the standing figure in the centre of the bas-relief represents Pamphilus, son of Mixiades, of the deme Ægilia, the seated figure being his sister Archippe.



Cinerary Urn in the British Museum.



Solid Funeral Urn in the British Museum.

The funeral rites of the Greeks and Romans have been collected with great research by Guichard in his 'Funérailles, et diverses Manières d'ensevelir des Romains, Grecs, et autres Nations,' 4to, Lyon, 1581; by Meursius, in his treatise 'De Funere Græcorum et Romanorum,' 12mo, Hag. Com., 1604; by Gutherius, 'De Jure Manium, seu de Ritu, More, et Legibus prisci Funeris,' 12mo, Par., 1613, reprinted in 4to, 1615, and again in 8vo, Lips., 1671; and by Kirchman, 'De Funeribus Romanorum Libri IV.,' 12mo, Hamb., 1605, and Lugd. Bat., 1672. See also the 'Ceremonies Funèbres de toutes Nations,' par le Sr. Maret, 12mo, Par., 1677; Stackeberg, 'Die Gräber der Hellenen,' and Kirchman, 'De Funeribus Romanis.'

For the funeral rites of the early Christians, the reader may consult Gretser 'De Funere Christiano,' 4to, Ingolst., 1611; and he may learn the customs of a later period from Durand, who wrote his 'Rationale Divinorum Officiorum' in the 12th century.

Investigations among the sepulchral tumuli of the northern nations show clearly that though before the introduction of Christianity the practice of cremation prevailed, that of burying the dead unburnt was observed also in the later periods of the pre-historic era, in Norway and Denmark, as well as throughout Germany, France, and England. (See Worsaae's 'Primeval Antiquities of Denmark,' translated by W. J. Thoms, 1849; and the articles CROMLECH and TUMULUS.)

Tacitus, in his treatise 'De Moribus Germanorum,' (c. 27) notices the simplicity of the funerals among the ancient Germans. Like the Romans, they burned their dead. The things which a German valued most were his arms and his horse: these were added to the funeral pile, with a persuasion that the deceased would have the same pursuits in his new state of existence. In the tomb of Childeric, king of the Franks, his spear, his sword, with his other warlike weapons, and even his horse's head, were found. (See Montfaucon, 'Monumens de la Monarchie Françoise,' tom. i. p. 10.)

Brand, in his 'Popular Antiquities,' vol. ii., p. 139 to 212, has much upon the English ceremonials, beginning with 'Watching with the Dead,' called in the North of England the Lake-Wake; he then proceeds with 'Laying out or streaking the Body;' setting salt or candles upon it; funeral entertainments; sin-eaters; mortuaries; following the corpse to the grave, and carrying evergreens, torches, and lights, at funerals; black used in mourning; the pall and under-bearers; doles and donations to the poor at funerals; church-yards; garlands in churches; and strewing flowers upon graves. Strutt's 'Manners and Customs,' Gough's 'Sepulchral Monuments of Great Britain,' and 'Notes and Queries,' vols. vi. to xii. of series 1, are other works to which the reader may refer for the older funeral rites of England.

Funeral entertainments, called silicernia and *cœnæ ferales* by the Romans, are of very ancient date. They are still kept up in the north of England, and are there called arvals or arvils. Among some extracts from the Berkeley Manuscripts, we read that "From the death of Maurice, the fourth Lord Berkeley, which happened June 8th, 1368, until his interment, the reeve of his manor of Hinton spent three quarters and seven bushels of beans in fatting one hundred geese towards his funeral, and divers other reeves of manors the like, in geese, ducks, and other poultry." Walsingham, speaking of those who attended Richard II.'s funeral at Langley, in 1399, says, "Nec erat qui eos invitaret ad prandium post laborem." ('Hist.' p. 405.) Shakspere has a well-known allusion to these feasts in 'Hamlet,' act i. sc. 2:

> "The funeral baked meats
> Did coldly furnish forth the marriage tables."

Lafitau, Charlevoix, and other travellers describe funeral ceremonies not unlike some of those above noticed as prevalent among the savages of America. Robertson ('Hist. of Amer.' vol. ii., b. 4) says, as they imagine that departed spirits begin their career anew in the world whither they are gone, they bury together with the bodies of the dead, their bow, their arrows, and other weapons used in hunting or war; they deposit in their tomb the skins or stuffs of which they make garments, Indian corn, venison, domestic utensils, and whatever is reckoned among the necessaries in their simple mode of life.

FUNERAL ORATIONS, discourses at funerals, are of great antiquity. The second book of Thucydides (c. 35, &c.) contains the laboured harangue delivered by Pericles at the solemn funeral ceremony instituted in honour of those Athenians who fell at the beginning of the Peloponnesian war; and other similar orations are extant in Greek. Augustus, at the early age of twelve, performed this office for his grandmother, and afterwards, when emperor, for the young Marcellus. Tacitus tells us that Nero pronounced a funeral oration over his wife Poppæa. Funeral orations were equally common over Christian martyrs; and Durand, in his 'Rationale,' says, "Ceterum priusquam corpus humo injecta contegatur, defunctus oratione funebri laudabatur." Fuller, in his 'Appeal of Injured Innocence' (part iii. p. 75), and Misson, in his 'Travels in England,' show the continuance of this practice to the close of the 17th century. Gay alludes to it in his 'Dirge:'

> "Twenty good shillings in a rag I laid,
> Be *ten* the parson's for his sermon paid."

The practice of delivering what may be properly called funeral orations, that is, addresses over the grave or at the interment of the dead by laymen, is common among the French, and is not unfrequent on great occasions among the people of the United States. In France the 'Oraisons Funèbres' of Bossuet and Fléchier have deservedly a high reputation.

FUNERAL SHOWS and GAMES frequently followed public funerals among the Greeks and Romans. An early example of this occurs in the funeral games celebrated by Achilles in honour of Patroclus. (Homer, 'Iliad.') As the dead were supposed to be delighted with blood, various animals, especially such as the deceased had been fond of, were slaughtered at the pile, and thrown into it: and, in still ruder times, captives or slaves. Among the Romans, gladiators, called *bustuarii*, were made to fight. Junius Brutus exhibited gladiators at his father's funeral; and the 'Adelphi' of Terence, at a later period, was produced for the first time at the funeral of Lucius Æmilius Paulus.

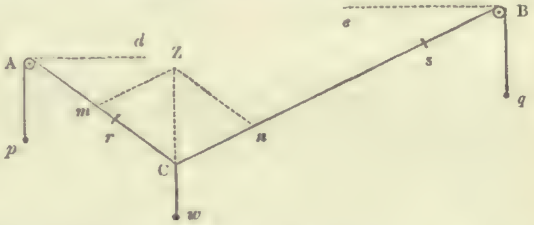
FUNGIC ACID, an acid discovered by Braconnot in the juice of most fungi. This acid exists partly in a free state in the *periza nigra*, and combined with potash in the *boletus juglandis*; it may be obtained from the juice of either of these vegetables by evaporating it to the consistence of a syrup, and treating it with alcohol. The portion insoluble in alcohol is the fungate of potash, which is to be decomposed by acetate of lead; the fungate of lead is to be decomposed by dilute sulphuric acid, or by hydro-sulphuric acid, by which the lead is separated in the state of sulphate or sulphuret, and the fungic acid is left in solution.

This acid, when pure, is colourless, very sour, uncrystallisable, and deliquescent; with lime it forms a salt difficult of solution, and with potash and soda deliquescent uncrystallisable salts; in these and some other properties it resembles impure malic acid. Some doubt exists as to whether it is a distinct acid, and M. Depaignes states that it is merely a mixture of malic, citric, and phosphoric acids.

FUNGIN, the name given by Braconnot to the fleshy substance of mushrooms, purified by digestion in a hot weak solution of alkali: it is whitish, soft, insipid, and but little elastic. It is not acted upon by water, alcohol, ether, dilute sulphuric acid, potash, or soda; it is dissolved by hydrochloric acid when heated, and it decomposes and is decomposed by nitric acid; the results are much gas, oxalic acid, a bitter yellow matter, and two fatty substances, one of which resembles wax, and the other suet; the latter is most abundant. It is a highly nutritious substance, and in many of its properties it strongly resembles cellulose. [CELLULOSE.]

FUNICULAR CURVE. [CATENARY.]

FUNICULAR MACHINE is a name given by some mechanicians to a cord or chain attached at one extremity to an immoveable point, the other end passing over a fixed pulley or friction wheel and having a weight suspended from it; a weight being also suspended from the cord or chain in some part of its length between the fixed extremity and the pulley. The cord or chain becomes thus a mechanical agent, since unequal weights, applied as has been said, may be in equilibrio.



Let A C B in a vertical plane be the position of a cord suspended between two points A and B, but capable of moving freely on a pulley at each of those points, and let w be a given weight suspended from any point C; the weights p and q, which should be applied to the cord, at the extremities vertically below A and B, in order to produce equilibrium, may be thus determined. Through C draw the vertical line C Z to represent the weight w, and draw Z m, Z n parallel to B C, A C, respectively: then, by mechanics, the lines C m, C n will respectively represent the strains in the directions A C, B C, and consequently the weights p and q, which, in the case of equilibrium, must be equivalent to those strains. Now since the angles A C Z, B C Z are known, representing them by a and b, the sine of the angle C m Z may be expressed by sin. $(a+b)$; and by trigonometry,

$$p = w\,\frac{\sin.\ b}{\sin.\ a+b},\quad q = w\,\frac{\sin.\ a}{\sin.\ a+b}:$$

therefore if the cord were attached to a fixed object at one end, as A or B, while capable of moving on a pulley at the other, and a weigh w were applied at any point C in its length, a weight q or p, found as above, would hold w in equilibrio.

Again, let the weights p, q, w, and the position of the pullies at A and B be given, the cord moving freely on the pullies and the weight w being capable of sliding by means of a ring along the cord; then the position of the parts A C, B C of the cord, when the system is in equilibrio, may be found in the following manner. Imagine $m\,n$ to be the parallelogram of forces; then since C Z, C m, Z m may be represented respectively by the known quantities w, p, q, the values of the angles A C Z and C Z m or B C Z may be found by trigonometry. With these, by a geometrical construction, or otherwise, the required positions may be readily determined, since A C and B C make with horizontal lines, as A d, B e passing through A and B angles equal to the complements of A C Z, B C Z.

A cord suspended in a vertical plane between two fixed points and acted on by weights placed at different points in its length, is called a *funicular polygon;* and the form of the suspended cord being given, with the weight to be applied at one angular point as C, the weights at all the other angular points, in the case of equilibrium, may be found thus. Let A and B be angular points on the left and right of C, and having determined the strains represented by C m, C n by the parallelogram of forces at C, construct a parallelogram at A and another at B, having vertical lines passing through A and B for the directions of their diagonals, and having two sides of each coincident in direction with the adjacent sides of the funicular polygon, also making the sides (A r and B s) on A C and B C equal to C m and C n respectively: then the diagonals will represent the weights to be suspended at A and C, in order to counteract the strains in A C and B C arising from the weight w at C. By forming parallelograms in a similar manner at the other angular points, the whole system may be in equilibrio. See 'Hutton's Tracts' (Tract 1, sect. 2, prop. i.).

In like manner may the equilibrium of the rafters in a curb-roof be determined. [Roof.]

FUNNEL, a hollow conical vessel with a small tube issuing from its apex; it is an instrument much used in common and domestic life for conveying fluids into vessels of small apertures, and in chemical operations it is used not only for this purpose but for the important one of filtering. [Filtration.] For the mere purpose of the transfer from one vessel to another of such fluids as do not act upon metals, funnels are commonly made of copper, pewter, or tin plate, and this is especially the case when they are employed for conveying powders into bottles. When, however, they are employed by the chemist with acid, alkaline, or such other solutions as dissolve or corrode the metals, then funnels are made of earthen or stone ware, or of glass. When used for filtration, especially in smaller and nicer operations, those of glass are always to be preferred.

FURFURAMIDE ($C_{30}H_{12}N_2O_6$). A product of the action of ammonia upon *furfurol*. It is isomeric with *furfurine*.

FURFURINE, a substance artificially formed by Mr. Fownes, possessing the properties of a vegetable alkaloid, and forming salts with acids. It is procured by boiling *furfuramide* with solution of caustic potash. Its formula is $C_{30}H_{12}N_2O_6$.

FURFUROL ($C_{10}H_4O_4$). When sugar or starch is acted upon with a mixture of dilute sulphuric acid and peroxide of manganese, there is produced in addition to formic acid, a peculiar oily matter which has been named furfurol. It is produced by the following reaction:—

$$\underbrace{C_{12}H_{10}O_{10}}_{\text{Starch.}} + O_4 = 2CO_2 + \underbrace{C_{10}H_4O_4}_{\text{Furfurol.}} + 6HO$$

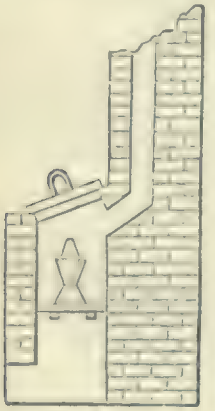
The same body can also be obtained by other reactions. Furfurol is an oily fluid, almost colourless at first, but on exposure to air, it gradually becomes brown, and finally black. It boils at 330° Fahr., and is easily soluble in water and in alcohol. Left in contact with ammonia for several hours, it is completely converted into a yellow semi-crystalline mass of furfuramide.

FURIES. [Eumenides.]

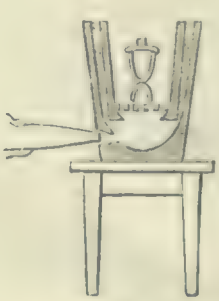
FURLONG. [Weights and Measures.]

FURNACE. The common grate is the most familiar example of a furnace. It is constructed of iron, and of various forms. The fuel is kept in it only by bars, in order to throw the heat out into the room. Indeed this is its principal use; and although its heat is barely sufficient to melt thin plate silver, yet many chemical operations may be performed in the common stove, and its flat sides or cheeks furnish a lower degree of heat, by which evaporation and digestion may be effected. The term furnace is, however, usually applied only to the fire-places used in manufacturing operations, such as those of chemists, metallurgy, and civil engineering.

For the smaller operations in chemistry a great variety of furnaces have been invented. The annexed figure represents one of these, a *wind furnace*: in this a very high temperature is produced without the use of bellows, by means of a powerful draught. The chimney of a wind furnace should be narrow and high; the furnace, represented as connected with and projecting from the chimney, should be of such a height as to allow the operator to look into it; it should be from 12 to 15 inches square, and furnished with moveable bars and a cover; every part exposed to the fire should be constructed of the best fire-resisting bricks. In the figure a crucible is represented as placed in the furnace, and its cover is on. This furnace is much employed in the reduction of metals, and in the assaying of copper and various other ores. The fuel used is either coke, a mixture of coke and charcoal, or anthracite. Another kind is the chemical *blast-furnace*. The exterior consists of a blue pot eighteen inches in height and thirteen inches in external diameter at the top. A small blue pot, of seven and a half inches internal diameter at the top, has the lower part cut off, so as to leave an aperture of five inches. This, when put into the larger pot, rests upon its lower external edge, the tops of the two being level. The interval between them, which gradually increases from the lower to the upper part, is filled with pulverised glass-blowers' pots, to which water enough has been added to moisten the powder, which is pressed down by sticks, so as to make the whole a compact mass. A round grate is then dropped into the furnace, of such a size that it rests an inch above the lower edge of the inner pot: the space beneath it therefore constitutes the air chamber, and the part above it the body of the furnace. A horizontal hole, conical in form, and 1½ inch in diameter on the exterior, is cut through the outer pot, forming an opening into the air-chamber at the lower part, its use being to receive the nozzle of the bellows. The fuel employed is coke, and the furnace is used with a pair of double bellows mounted on an iron frame: the furnace being raised upon an iron stool so as to bring the aperture of the air-chamber to a level with the nozzle of the bellows. Such a furnace as this is sufficiently powerful to melt pure iron in a crucible in 12 or 15 minutes. It will effect the fusion of rhodium, and even pieces of pure platinum have sunk together into one button in a crucible heated by it; all kinds of crucibles, including the Cornish and the Hessian, soften, fuse, and become frothy in it. Mr. Faraday had such a furnace as this long in use at the Royal Institution.

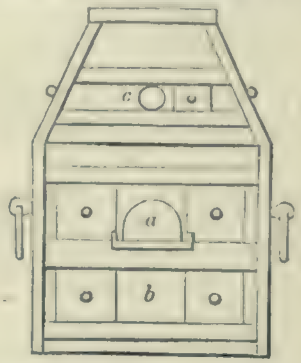


Wind Furnace.

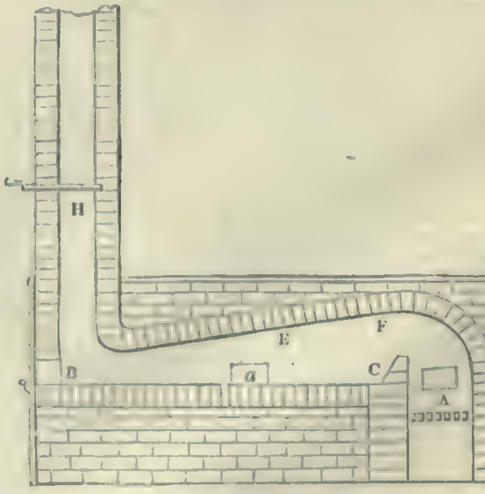


Blast Furnace.

The *assay* or *cupelling furnace* is a small furnace made of iron, lined with fire-proof clay, and containing a muffle; it is used principally for the cupellation of gold and silver, which is placed upon a cupel in the muffle, previously heated to redness. The interior of the furnace contains merely the muffle resting upon two bars of iron; it is put about two-thirds into the furnace, and there is consequently left a space between it and the back part of the furnace. In the annexed cut, *a* is the orifice of the muffle, which may be closed by iron slides placed at the side. The opening *b*, placed below the grate, and provided with slides, serves as well as the upper opening *c* to regulate the draught. Charcoal is used in this furnace.

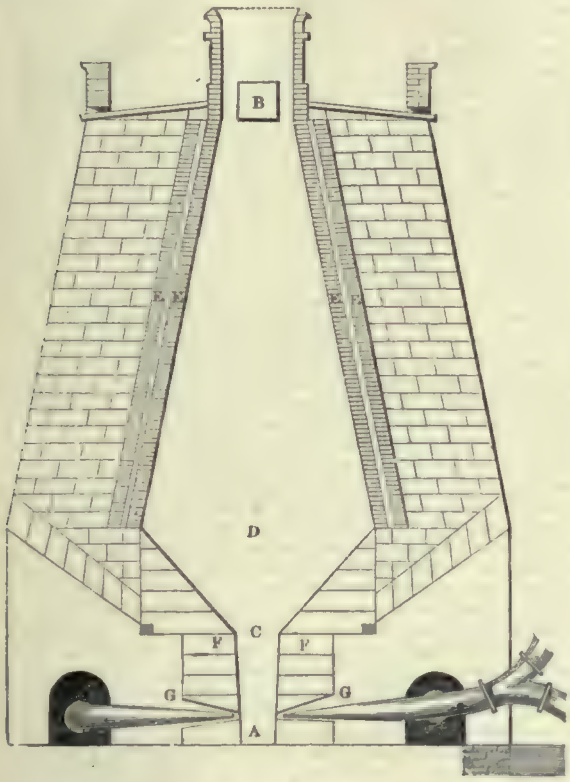


Recently gas furnaces for the analysis of organic substances, and for the fusion of metals, have been ingeniously contrived: the first by Dr. Hofmann, and the latter by Mr. Griffin. The first will be found described in the 'Quarterly Journal of the Chemical Society,' vol. xi., p. 30, and the second in the 'Chemical News,' No. 3. For metallurgic operations on the large scale, as well as in making alkalies, red lead, &c., the *reverberatory furnace* is much used. This is shown in the annexed figure. A is the space furnished with a grate or bars, to contain the combustible, which is either coke, coal, or wood, according to circumstances; B E F is the part on which the flame acts, E F is the roof, B C



Reverberatory Furnace.

the hearth on which the substance to be heated is placed, and this is either horizontal or inclined; lastly, C is a low wall or the bridge of the furnace, which retains the fuel in its place, and serves to direct the flame towards the roof: *a* shows the opening of the furnace, usually placed at its side; through this the substance to be heated is introduced, and it is afterwards closed; often also there is an opening at B, to allow of melted metal to flow out. H is a very high chimney that produces the draught, and which may be closed by a damper. As this furnace is employed for a vast number of purposes, it is evident that various forms must be used; these however it will not be necessary to describe.



Pig-iron Furnace.

The *pig-iron furnace* (see preceding figure) is that used in South Wales and elsewhere in the making of pig-iron; the height of this furnace, from the bottom at A to the filling-place at B, is 50 feet; the height of the hearth, from A to C, 8½ feet; from C to the top of the boshes at D, 8½ feet. The diameter of the hearth from A to C increases from 3 feet to 3½ feet. The extreme width at the top of the boshes D is 11 feet. The diameter of the charging-place B is 6 feet. E E E E, the lining, is composed of a double circle of fire-bricks, about 15 inches long each, with a space for an intermediate packing of sand. F F, the hearth, is constructed of large blocks of breccia, or plum-pudding stone; G G are the tuyers or openings by which the blast is discharged into the furnace from the blowing cylinder, which is worked by a steam-engine. The contents of this furnace are 5015 feet; and it is capable of producing 100 tons of pig-iron weekly.

This important subject of blast-furnaces will receive further elucidation in IRON MANUFACTURE.

In connection with furnaces generally, the new inventions are so numerous as to be quite beyond even enumeration in an article such as the present. Some of the improvements relate to the furnaces of locomotives; some to those of marine engines; some to those of stationary engines; and some to furnaces in general. In one class of cases the patentees seek to economise space, in another fuel, and in another to effect the consumption or prevention of smoke. Some relate to metallic furnaces, and some to brick-furnaces. In some the object is to raise steam in great quantity; while in others it is to obtain rapidity rather than quantity. Many of these new forms of furnace will receive brief notice in the articles relating to Metallurgic, Manufacturing, and Civil Engineering subjects.

FURNISHED LODGINGS. [LODGINGS.]

FURRIERY; FUR DRESSING. The various kinds of fur imported from foreign parts, as well as some found in our own country, may be classed according to their use as *felted furs* and *dressed furs*.

Felted furs. These include all such as are employed in hat-making; and are principally the skins of the hare, the rabbit, the beaver, and the neutria. If the skin be taken off the animal in winter when the fur is full, soft, and fine, it is called "seasoned," and sells at the highest price; but if taken off at any other period of the year, it is comparatively short, coarse, hairy, and less valuable, and obtains the name of "unseasoned skin."

In the preparation of *hares' fur* for the hatter, the skin, after being opened and spread out flat, is rubbed with a kind of saw called a *rake*, for the purpose of clearing away the dirt and dried blood without detaching any of the fur itself. This done, the skin is damped on the *pelt* or inner side; and several are pressed one on another to remove creases and irregularities. Next ensues the separation of the furry covering from the felt beneath. This covering is of two kinds: an external coat of long hairs which possess no felting properties, and an internal coat of fine or true fur. These are removed separately. A pair of shears, something like those used in shearing sheep, are worked all over the surface of the skin so as to cut off the coarse hair without damaging the fine fur beneath; and to effect this properly is a difficult operation. The skin before this shearing was of a brownish colour, but when the external hair is removed the fur beneath appears as a beautiful jet-black glossy fibre. To remove this fur is the next stage. The skin, extended smooth and even, is placed upon a square cutting-board, made of willow, wetted occasionally to avoid blunting the edge of the knife employed in the cutting. This knife is about six inches long by three broad, and has a rough edge; it is shaped something like a cheese-cutter, so as to be used alike backwards and forwards. With such a knife the fur is cut gradually in every part of the pelt; the knife follows the direction which the fur naturally takes on the animal's skin: that is, from the head towards the tail. The whole of the fur from one skin is either collected together as a light fleecy mass, or is separated into parcels according to the different qualities of the different parts.

The preparation of *rabbits' fur* for the hatter is somewhat different from the above in its earlier stages, on account of the greater greasiness of the pelt or inner surface of the skin. By the use of a knife in a peculiar way, the thin cuticle on which the grease or fat is deposited is stripped off, bringing the impurities away with it. The surface beneath is then rubbed with whiting. The rabbit skin, like that of the hare, has two kinds of hair or fur; but the coarser, instead of being removed by shearing, requires to be *pulled;* this is done by a short knife about three inches long, held against a leathern shield worn over the thumb: the hairs are grasped, a few at a time, between the knife and the thumb, and pulled out. A double care is here requisite: to avoid cutting the hair instead of pulling it, and to avoid pulling or cutting the fine fur beneath. When this is done, the fine fur is cut off in the same manner as hare's fur.

For the *neutria skins*, obtained from the coypou of America, the processes are nearly the same. The skin has derived its name (variously written *neutria*, *nutria*, *neutra*, *nuetra*) from the Spanish name for an otter, to whose skin it bears some resemblance. It is full of fat and grease, and requires a thorough washing with soap and boiling water before being "pulled." The outer or coarse hairs are treated like those of the rabbit and not like those of the hare; being stronger, too, they require a sharper knife and a stronger pull for their extraction. Not only the pelt side, but also the fur-side is full of grease, and need a thorough purification before the removal of the hairs and fur. When the external hair has been pulled, the inner fur is cut in the same way as the others.

The skin of the *beaver* is, in many respects, the most serviceable of them all for the hatter's purpose. It is, however, so full of grease that the pelt requires to be scoured with fullers' earth and whiting before it attains a sufficient state of cleanness. The coarse hairs are pulled out by the knife and thumb; and being of no use to the hatter, they are sold as stuffing for cushions. Then comes the cutting or cropping, which is, at the present day and in the largest establishments, effected by a very beautiful machine. There is a long broad and sharp blade, equalling in length the full width of the beaver-skin, and so adjusted as to fall rapidly with a chopping action against or near the edge of another blade beneath. The skin is placed between the two, and is attached to a piece of mechanism by which it is drawn gradually from end to end between them; as it passes, the sharp blade crops the fur from off the pelt, which it does so effectually that not a particle of fur is left behind, and yet the pelt is not cut through in any part. The fur falls down in a light flocculent layer on an endless apron beneath, from whence it is removed when the pelt is denuded. This fur is of three or four different qualities, that from the cheek being the finest and most valuable; and to separate them one from another a method at once simple and elegant is adopted. The fur is placed in a large chest or trough, where it comes within the action of a fan revolving two thousand times in a minute; the current excited by this fan is so violent that it whirls the fur along a hollow trunk or channel fifty feet in length. During the passage of the fur, the relative specific gravities of the filaments effect a separation without any farther interference: those which are largest and coarsest fall first, and are deposited on the bottom of the first compartment of the trough; those which are next heavier are deposited farther on; and lastly, the finest and best parts of the fur are blown to the extreme end of the trough, whence they can be taken without admixture with any of the others.

The cutting of the fur from the pelt by machinery has been attempted for various furs, but it has succeeded only with the beaver;

this is said to be owing to the circumstance that the beaver-pelt is very regular in thickness and uniform in surface; whereas, most of the other pelts are irregular or unequable. If the blade of the machine by passing over an irregular part of the pelt should cut off a small bit of the latter, it would be the means of spoiling the mass of fur unless removed. Attempts have been made to detach the fur from the pelt by chemical instead of mechanical means. In tanning and leather-dressing, the hair and wool of the animal are often loosened by being exposed for some hours to the action of some acid or other chemical agent: and it has been supposed that the same result would be obtained with the furs used by hatters; but it is found that, though separable by such means, the fur is injured in its felting properties—an objection fatal to the adoption of the plan.

Beaver skins have recently been brought to an excellent state for robes and other garments, by processes devised by Mr. Roberts, a London furrier. Other kinds of fur besides the four above-named are employed in hat-making, but are not so generally serviceable. *Mole fur* is fine and regular, but is almost too short to be available. *Musquash* or *musk-rat fur* is employed to some considerable extent. *Seal-fur* presents a dull appearance when worked up as a covering to a hat, being deficient in the delicate glossiness which distinguishes beaver. *Otter fur* is finer than that of the seal, and is so far more serviceable, but it does not take a good black-dye. According to the price at which a hat is intended to be sold, so is the selection of the fur employed. A good beaver hat contains in the foundation or body a mixture of fine wool with rabbit's fur, and in the covering beaver-fur alone; this is the standard, from which a departure takes place according to the price. The use of this last-named fur, however, has much lessened in recent years.

Some kinds of fur which are rather deficient in the felting property are made to undergo a process termed "carrotting," so called from the colour imparted thereby to the fur. This consists in wetting the skin (before the fur has been yet cropped from the pelt) with dilute sulphuric acid, and quickly drying it either near a strong fire or by means of a heated iron passed over it. The fur of the same species of animal often differs very much in felting quality, according to the district where the animal is found. Thus, the fur of the rabbit is said to possess a stronger felting quality when obtained from an animal reared near the sea-coast than from an inland animal; those of the eastern coast of England, from Lincolnshire to the Tweed, are considered the finest. The fur of the English hare, as a second example, is found to be both finer in quality and stronger in felting power than that of any other variety of the hare.

Dressed Furs.—By this term may be designated those furs which are retained on the original pelt, and in that state worn as garments or trimmings of garments, in the forms of cloaks, tippets, cuffs, collars, &c. Such an employment of furs was very much a matter of necessity among the rude tribes where the custom was first followed. At first the skins were worn almost in the state in which they were taken from the animals: but as the use of luxuries advanced, the art of dressing the skins became established, and fur took rank as an adornment as well as a covering.

The dressing of furs for this purpose, or *furriery*, is much more simple than the preparation of felting-fur for the hatter, since it does not involve the separation of the filaments from the pelt beneath.

The fur-hunters of America, when they have captured a beaver or other fur-bearing animal, strip off the skin, and hang it up to dry, either in the open air, or in a dry and cool room where there is no fire. Great importance is attached both to the drying and to the careful packing of the skins; for if the slightest degree of putrefaction ensues, the fur loses its firm hold of the pelt, and is not fit for furriers' purposes. When the skins are brought to England, and placed in the hands of the furrier, he examines them minutely, to see that the drying has been properly effected, and the pelt in a firm state. He then proceeds to the two processes which constitute the main part of his business, namely, extracting the greasiness from the pelt, and also a kind of oil which is in the fur itself. The skin is put into a liquid containing bran, alum, and salt; and after sufficient steeping it is worked about and scoured, so as to remove the grease. The fur is cleansed from its oiliness by an application of soda and fine soap. The cleansed skin is finally washed thoroughly in cold water, and hung up to dry. The alum and other ingredients employed in scouring the pelt effect a kind of tanning or tawing process, by which the pelt is converted into a sort of thin leather, and thereby rendered more durable.

When thus far prepared, the skins are ready to be worked up into the form of garments, or materials for garments. In order to give the surface of the fur a uniform length and colour of fibre, it is often necessary to cut up a great many skins, and sew certain pieces of each edge to edge; for it is rarely if ever the case that every part of the same skin is of one uniform colour. The cutting up of a skin thus becomes an important affair; for unless considerable tact be exhibited, many of the smaller pieces would become waste. The furs which are used for these purposes are in general different from those selected for felting; they comprise usually the gray, the silver, and the black fox, the sable, the bear, the lynx, the ermine, the mink, the chinchilla, the marten, the wolf, the fitchet, and a few others of less common character.

The preservation of furs, when kept in stock for manufacturing purposes, is a point of considerable importance, from the several sources of injury to which they are exposed. If kept too damp, they rot; if too dry, they diminish in weight. "The great enemy to all furs," says a practical writer on this subject in the 'Encyclopædia Britannica,' "is the common moth. This destroys the felting principle. Whenever the slightest appearance in the fur indicates the secure lodgment of this little creature, it ought immediately to be used; or, if this cannot be done, it should be taken out of the paper-bags, and broken all over with a small switch rod, or, what will answer the purpose still better, a hatter's bow. The same rules apply to the keeping of skins in good condition as to fur. The situation ought to be cool, dry, and well aired. They will seldom keep longer than twelve or eighteen months, without running great risk of suffering injury from the moth or black beetle. Too many ought not to be heaped together, and particularly if they be rabbit skins, because the fat or grease about these skins will get heated, run amongst the fur, and become of such an acrid nature as to corrode the very pelt itself. Many persons are inclined to keep hare and rabbit skins a long time, from a notion that the fur upon them will increase in length from the moisture left in the pelt. This is an entirely erroneous opinion. Any one who will make the experiment will find that the amount of fur obtained off any given quantity of skins is much greater in weight when manufactured immediately after they are taken off the animal, than after having been kept for six or twelve months."

FURS and the FUR-TRADE. The use of furs appears to have been introduced into civilised Europe by the northern conquerors. In the 6th century the skins of sables were brought for sale from the confines of the Arctic Ocean to Rome, through the intervention of many different hands, so that the ultimate cost to the consumer was very great. For several centuries after that time furs could not have become at all common in Western Europe. Marco Polo mentions as a matter of curiosity in 1252, that he found the tents of the Cham of Tartary lined with the skins of ermines and sables, which were brought from countries far north, from *the land of darkness*. But in less than a century from that time the fashion of wearing furs must have become prevalent in England; for in 1337 Edward III. ordered that all persons among his subjects should be prohibited their use unless their free incomes amounted to one hundred pounds a year. The furs then brought to England were furnished by the traders of Italy, who procured them from the north of Asia.

The fur trade was taken up by the French colonists of Canada very soon after their first settlement on the St. Lawrence; and through the ignorance of the Indians as to the value of the skins which they sold, and of the trinkets and other articles which they took in payment, the traders at first made very great profits. The animals soon becoming scarce in the neighbourhood of the European settlements, the Indians were obliged to extend the range of their hunting expeditions, in which they were frequently accompanied by one or other of the French dealers, whose object it was to encourage a greater number of Indians to engage in the pursuit, and to bring their peltries, as the unprepared skins are called, to the European settlements. When the hunting season was over, the Indians came down the Ottawa in their canoes with the produce of the chase, and encamped outside the town of Montreal, where a kind of fair was held until the furs were all exchanged for trinkets, knives, hatchets, kettles, blankets, coarse cloths, and other articles suited to native wants, including arms and ammunition. A large part of the value was usually paid to the Indians in the form of ardent spirits, and scenes of riot and confusion were consequently of frequent occurrence.

The next stage in the Canadian fur-trade was when some of the European settlers, under the name of *Coureurs des Bois*, or wood-rangers, set out at the proper season from Montreal in canoes laden with various articles considered desirable by the Indians, and proceeded up the river to the hunting-grounds. Here they remained for an indefinite time, sometimes longer than a year, carrying on their traffic with the Indian hunters; and when their outward investments were exhausted, they returned, their canoes in general loaded with packs of beaver-skins and other valuable peltries. While engaged in these expeditions, some of them adopted the habits of the tribe with whom they were associated, and formed connections with the Indian women. The half-caste children make excellent *voyageurs*, and are readily employed by the company in that capacity.

This trade was for some time extremely profitable. The men by whom it was conducted were usually without capital; and their investments of European goods were furnished by the storekeepers of Montreal, who drew at least their full proportion of profit from the adventure. The return cargo was generally more valuable than the investments, in the proportion of six to one, in the tariff of the Canadian markets. Thus, where the investment amounted to 1000 dollars, and the peltries returned sold for 6000, the storekeeper first repaid himself the original outlay, and usually secured for himself an equal amount for interest and commission, after which the remaining 4000 dollars were divided between himself and the Coureur des Bois.

The Hudson's Bay Company, established with the express object of procuring furs, was chartered by Charles II. in 1670, with the privilege of exclusively trading with the Indians in the vast and not well defined region lying to the north and west of the great inlet from which the company takes its name. This association founded several establishments, and has ever since prosecuted the trade under the direction of a governor, deputy-governor, and a committee of management chosen from among the proprietors of the joint-stock, and resident in London. The company's charter not being confirmed by act of parliament, it was considered that all British subjects were entitled to engage in the trade with those regions; and, in conformity with this notion, a partnership was formed in 1783 under the name of the North-West Company, which proved a powerful competitor. This company consisted of twenty-three shareholders or partners, comprising some of the most wealthy and influential British settlers in Canada, and employed about 2000 persons as clerks, guides, interpreters, and boatmen or *voyageurs*, who were distributed over the face of the country. Such of the shareholders as took an active part were called agents; some of them resided at the different ports established by the company in the Indian territory, and others at Quebec and Montreal, where each attended to the affairs of the association. These active partners met once in every year at Fort William, one of their stations near the Grand Portage on Lake Superior, in order to discuss the affairs of the company and agree upon plans for the future. The young men who were employed as clerks were, for the most part, the younger members of respectable families in Scotland, who were willing to undergo the hardships and privations accompanying a residence for some years in these countries, that they might secure the advantage of succeeding in turn to a share in the profits of the undertaking: the partners, as others died or retired, being taken from among those who, as clerks, had acquired the experience necessary for the management of the business. This company had a settlement, called Fort Chippewyan, so far west as the Lake of the Hills, in 110° 26′ W. long.; and some of the Indians who traded with the persons stationed at this fort came from beyond the Rocky Mountains.

A great degree of jealousy and hostility arose between the respective agents of the Hudson's Bay and North-West companies, which more or less impeded the operations of both parties for several years, until in 1821 a junction of the two was effected, and the trade has since been prosecuted peacefully and successfully. Their presumed exclusive right of trading throughout the vast region which they have made the scene of their operations, is still guarded with extreme jealousy, as we shall see further on. All the furs collected by the Hudson's Bay Company are shipped to London,—some from their factories of York Fort and Moose River, in Hudson's Bay; other portions from Montreal; and the remainder from the Columbia River.

The fur-trade is prosecuted in the north-western territories of the United States by an association called the North American Fur Company, the principal managers of which reside in New York. The chief station of this company is Michilimackinac, to which are brought all the peltries collected at the other ports on the Mississippi, Missouri, and Yellowstone rivers, and through the great range of country extending thence to the Rocky Mountains. This company employs steam-boats for ascending the rivers, which penetrate with ease to regions which could formerly be explored only through the most painful exertions in keel-boats and barges, or by small parties on horseback or on foot.

We shall here notice a few of the principal fur-bearing animals, referring the reader to the NATURAL HISTORY DIVISION for more specific information.

The *ermine*, called by way of pre-eminence "the precious ermine," is found almost exclusively in the cold regions of Europe and Asia. The *stoat*, which in fact is identical with the ermine, but the fur of which is greatly inferior to that of the European and Asiatic animal, is found in North America. The fur of the ermine is of a pure whiteness throughout, with the exception of the tip of the tail, which is black; and the spotted appearance of ermine skins, by which they are peculiarly known, is produced by fastening these black tips at intervals on the skins. The animal is from 14 to 16 inches long from the nose to the tip of the tail, the body being from 10 to 12 inches long. The best fur is yielded by the oldest animals. They are taken by snares and in traps, and are sometimes shot, while running, with blunt arrows. The *sable* is a native of Northern Europe and Siberia. The skins of best quality are procured by the Samoids, and in Yakutsk, Kamtchatka, and Russian Lapland: those of the darkest colour are the most esteemed. The length of the sable is from 18 to 20 inches. It has been considered by some naturalists a variety of the pine-marten. *Martens* are found in North America as well as in Northern Asia and the mountains of Kamtchatka: the American skins are generally the least valued, but many among them are rich and of a beautiful dark-brown olive colour. The *fiery fox*, so called from its brilliant red colour, is taken near the north-eastern coast of Asia, and its fur is much valued, both for its colour and fineness, in that quarter of the world. *Neutria* skins are obtained from South America, and the greater part of the importations in this country come from the states of the Rio de la Plata. These skins are of comparatively recent introduction; having first become an article of commerce in 1810: the fur is chiefly used by hat-manufacturers, as a substitute for beaver. *Sea-Otter* skins were first sought for their fur in the early part of the 18th century, when they were brought to Western Europe from the Aleutian and Kurile Islands; where, as well as in Behring's Island, Kamtchatka, and the neighbouring American shores, sea-otters are found in great numbers. The fur of the young animal is of a beautiful brown colour, but when older the colour becomes jet-black. The fur is exceedingly fine, soft, and close, and bears a silky gloss. Towards the close of the 18th century furs had become exceedingly scarce in Siberia, and it became necessary to look to fresh sources for the supply of China and other Asiatic countries. It was about the year 1780 that sea-otter skins were first carried to China, where they realised such high prices as greatly to stimulate the search for them. With this view several expeditions were made from the United States and from England to the northern islands of the Pacific and to Nootka Sound, as well as to the north-west coast of America. The Russians then held and still hold the tract of country most favourable for this purpose, but the trading ships which frequent the coast are enabled to procure these skins from the Indians. *Fur-seals* are found in great numbers in the colder latitudes of the southern hemisphere. South Georgia, in 55° S. lat., was explored by Captain Cook in 1771, and immediately thereafter was resorted to by the colonists of British America, who conveyed great numbers of seal skins thence to China, where very high prices were obtained. The South Shetland Islands, in 63° S. lat., were greatly resorted to by seals, and soon after the discovery of these islands in 1818, great numbers were taken: in 1821 and 1822 the number of seal skins taken on these islands alone amounted to 320,000. Owing to the system of extermination pursued by the hunters, these animals are now almost extinct in all those islands, and the trade for a time at least has ceased. The seal-fishery, or hunting, in the Lobos Islands, is placed under restrictive regulations by the government of Montevideo, and by this means the supply of animals upon them is kept pretty regular. *Bears* of various kinds and colours, many varieties of *foxes, beavers, racoons, badgers, minks, lynxes, musk-rats, rabbits, hares,* and *squirrels*, are procured in North America. Of all the American varieties, the fur of the *black fox*, sometimes called the silver fox, is the most valuable; next to that in value is the fur of the *red fox*, which is exported to China, where it is used for trimmings, linings, and robes, which are ornamented in spots or waves with the black fur of the paws of the same animal. The fur of the *silver fox* is also highly esteemed. This is a scarce animal, inhabiting the woody country below the falls of the Columbia river. It has long thick fur of a deep lead colour, intermingled with long hairs white at the top, forming a lustrous silver-gray, whence the animal derives its name. The hides of *bisons* (improperly called buffaloes), of the *sheep* of the Rocky Mountains, and of various kinds of *deer*, form part of the fur-trade of North America; and sometimes the skin of the *white Arctic fox* and of the *Polar bear* are found in the packs brought to the European traders by the most northern tribes of Indians. There is but one species of fur which is peculiar to England, the *silver-tipped rabbit* of Lincolnshire. The colour of the fur is gray of different shades, mixed with longer hairs tipped with white. This fur is but little used in England, but meets a ready sale in Russia and China; the dark-coloured skins are preferred in the former country, and the lighter-coloured in China.

The fur-sales of the Hudson's Bay Company are held every year in the month of March, and being of great magnitude, they attract many foreign merchants to London. The purchases of these foreigners are chiefly sent to the great fair at Leipsic, whence the furs are distributed to all parts of the continent of Europe.

Circumstances of a remarkable kind have recently given a new interest to the American fur-trade, in relation to its political, proprietary, and commercial aspects. In the articles HUDSON'S BAY TERRITORIES, OREGON, and VANCOUVER, in the GEOGRAPHICAL DIVISION of this Cyclopædia, an account is given of the mode in which the Hudson's Bay Company's operations received an extension on the coast of the Pacific. Since the period when those articles were published, important events have occurred which call for some notice here, seeing that they are likely to affect the future course of the fur-trade.

In 1856 gold was discovered on the banks of Fraser River, within a short distance of Vancouver Island, about 800 miles north of San Francisco, in California; and in 1857 the discovery was amply confirmed. The region belonged to England, but had been only interesting to Englishmen in so far as the Hudson's Bay Company had established fur-hunting stations upon it. Now, however, a new order of things commenced. If the gold were at all plentiful, it was certain to attract a large number of diggers from California, and adventurers from other quarters, and to bring about a state of society with which the company's servants would be incompetent to deal. The company have uniformly discouraged trading and colonising by any free trading community, in order to retain the monopoly of the fur-trade in their own hands. When the island of Vancouver was leased to them by the Crown, there was a virtual undertaking by them to colonise it; a condition which, though not actually evaded, has been but ill-fulfilled. A town, called Victoria, was established on the island; and this became the head-quarters of the company's operations in that region. The island is little more yet than an uncleared forest, with 20,000 aboriginal inhabitants and a small number of Europeans. Victoria has many of the elements for a magnificent port; it was a mere hamlet of 400 souls when the gold discovery was made; but it was speedily overrun by 6000 or 8000 adventurers, who came to it from all quarters as the nearest town to the gold-fields. Fortunately, Mr. Douglas, the chief officer, was a man of tact and energy, and proved himself equal to the difficulties of his new position. It must be understood that the company had no governing power in the island; they held a lease of the soil for ten years (1849 to 1859) for trading purposes, on condition of establishing a colony and disposing of land to emigrants; but the governor was appointed by the Crown, and legislative houses were chosen by the people. The company as well as the government felt that such an important island could not long remain in this anomalous condition; for it has all the capabilities for being a great naval station for British ships on the eastern margin of the Pacific, and is moreover very advantageously situated for commerce. It had become well understood that the lease to the company would not be renewed in 1859; but the gold discoveries on the adjacent coast rendered additional arrangements necessary. In July 1858 the government brought a bill into the House of Commons for the establishment of a new colony to be called New Caledonia, to comprise the island of Vancouver and a wide stretch of the adjacent mainland. This mainland portion extends from the Pacific to the Rocky Mountains, about 300 miles; and from latitude 49° N. to about 55°, a little over 400 miles. No governor or magistrate of any kind existed within those limits, for Mr. Douglas only governed the island; and therefore speedy legislation became necessary, to prevent anarchy, and to secure the region to the British crown. The act proposed by the bill was to endure only until 1863, to afford an opportunity for modification in the governmental regulations. With a few amendments and alterations the bill became a law (21 & 22 Vict. c. 99); but the name of the colony was changed from New Caledonia to British Columbia. A disagreement with the United States Government, in 1859, did not affect the general ownership of this new colony, but only referred to the small island of St. Juan, which is claimed by both nations, owing to a want of clearness in a treaty which settles the boundary in those regions at the 49th parallel of north latitude. The eventual colonisation of British Columbia will interfere a little with the fur-hunting arrangements of the Hudson's Bay Company; but it will exert still more influence by introducing the principles of unshackled trade into a region where strict monopoly has hitherto been maintained. There seems a probability, also, that the fur-trading privileges of the company in other quarters will shortly be curtailed; the wishes of the legislature in this respect were pretty strongly expressed in 1858 and 1859, in reference to certain licence-privileges terminable in 1860.

A committee of inquiry, appointed by the House of Commons in 1857, was the means of bringing to light much curious information concerning the fur-trade. Occurring before the events just noticed were fully known, the inquiries could not bear relation to the gold deposits, nor to the new political relations of the western coast; but as far as concerns the fur-trade, the information remains as true in 1860 as it was in 1857. This is the more valuable, because the company have always been very chary of communicating information concerning their commercial transactions; on this account, a few facts may suitably be introduced here.

The company's vast territories are ruled by a governor-in-chief, invested with large powers. For forty years this office has been held by Sir George Simpson. Under him are sixteen chief factors, controlling districts or provinces into which the territories are divided. Subordinate to these are twenty-five chief traders. Each factor or trader has a sort of metropolis or head-quarters, called a fort, factory, or post, large enough to accommodate a considerable number of persons, and strong enough to be defended against any hostile attacks by Indians. The chief factors and chief traders are not salaried servants; they are partners or shareholders, receiving, in return for their personal services, a definite percentage on the company's annual trading net profits. Under the factors and traders, or associated with them, are five surgeons, forty chaplains or missionaries (belonging to four Christian denominations), about a hundred and fifty clerks and postmasters or messengers, and twelve hundred servants or subordinates. Nearly all these persons receive their appointment from the directors of the company, and a large number of them are Orkney men. They go out at first under an engagement for five years; but most of them stop much longer, some as long as twenty-five or thirty years, and the average as many as fifteen. The first wages for servants, labourers, &c., is about 20*l.* a year, besides board, lodging, and other necessaries; and the men gradually rise in station and in salary according to their ability. The chief factors, with the governor-in-chief, constitute the members of a council, which meets annually in June, to review the whole events of the past year, and to make arrangements for the year next ensuing. If the factors from the more distant stations cannot conveniently come to make up a *quorum* of seven or eight, a few of the chief traders are admitted to complete the number. The governor-in-chief and the council of factors bear some such relation to the Hudson's Bay Board in London, as the governor-general and supreme council of India bore to the board of directors in the old East India Company; there are certain general rules and orders sent out from home, but a wide discretion is left in the application of them.

So much for the relations between the company and their white servants; those with the natives bring us at once to the present mode of managing the fur-trade. Besides the persons already mentioned, the company employ five hundred *voyageurs*, to manage the canoes on the rivers and portages; and an indefinite number of persons as servants, labourers, hunters, fishers, and assistants generally, just as their services are wanted. Nearly all these persons are Canadians or Europeans; or they are half-breeds, descendants of white men and native women. The Indians, the natives proper, are not servants of the company; they kill the animals, and bring the skins and furs to the trading posts; but each one is an independent trader, bartering and bargaining for himself. The independence is, however, a peculiar one. During the summer months the Indians work for the company at any odd jobs, if willing, and if their services are needed: but when winter is coming on, they set off to the hunting-grounds. Being poor and improvident, they have nothing to set out with; the company give them blankets, guns, and ammunition, which are to be paid for in the following spring, each article being valued at so many beaver-skins. During the winter they obtain what furs they can. The company do not inform them what kinds are most highly valued, or bring most money, in England. Dr. Rae, the enterprising Arctic explorer, and one of the most energetic of the company's servants, said in evidence before the committee:—"The company's tariff with the Indians is formed in a peculiar way, and necessarily so. The sums given for furs do not coincide with the *value* of the furs traded for; because the musk-rat, or the less valuable furs, are paid for at a higher [proportionate?] rate. Were the company to pay for the fine furs at the same rate, the Indians would hunt up the finer furs, and destroy them off, as has been done all along the frontier of America; and we should require to reduce the price for the musk-rat and the inferior furs, and the Indians would not hunt them at all. The Indians would never understand our varying the prices of the furs according to the prices here (in England)." The meaning of this is, that the company, by giving a comparatively high price for common furs, realise only a small profit thereon; but they get an enormous profit on the best furs, such as the beaver and the silver fox; and it may be doubted whether their motive is altogether so disinterested as is stated, in concealing the European estimate of furs from the knowledge of the Indians. These Indians would gladly obtain ardent spirits in barter for furs; but the company have wisely forbidden this, except in a few frontier districts, where the company have to compete with the Americans, who entertain no such scruples. The company send out yearly about 60,000*l.* worth of blankets, cloth, guns, ammunition, knives, and miscellaneous articles; of which about one-third is for the use of the company's servants, and two-thirds for barter with the Indians for furs. Money is never paid for the furs, except near the frontiers, where competition exists. The Indians mostly live upon fish and buffalo; all their other necessaries (and luxuries) they obtain from the company by bartering furs. Beads, needles, thread, and numerous small articles, are kept at the trading posts, not for barter, but as presents to retain the good will of the natives. The company are *nursing* the northern half of their territories: that is, encouraging the hunters to bring in the cheaper and more plentiful furs, instead of exhausting the stock of those which are scarcer and more valuable; as a consequence, the whole stock and the whole trade have been gradually becoming more valuable between 1840 and 1860. An average beaver-skin is the standard of currency between the company and the hunters; European articles are worth so many "beavers" each. A sort of tariff was agreed upon many years ago, and is only in a slight degree altered, once now and then. The company are virtually the makers of this tariff, for they sedulously keep the Indians in ignorance of the relative values of furs in Europe. Ten musk-rats equal one beaver; so many beavers equal one silver-fox; &c. But when we come to compare English goods with Indian furs, the nature of the company's profit peeps out. A blanket equals "four beavers;" a gun (bought at Birmingham for 22*s.*) is equal to "twenty beavers;" a slop-made coat is equal to "five or six beavers." A gun, in consideration of the relative high price given for inferior skins, may sell for only 4*l.* or 5*l.* in musk-rats; but estimated in silver-foxes, it sometimes brings 50*l.* worth—a startling profit on a cheap Birmingham gun. Beaver fur has varied in price, during the last few years, from 8*s.* to 30*s.* per lb. in the London market: an average skin yielding about 1 lb. of fur; so that the company's profits vary greatly, seeing that the Indian tariff does not vary with the London prices. Moreover, it is asserted by the company, as a drawback on their apparently excessive profits, that a period varying from three to seven years elapses before capital can be returned: that is, between the time at which goods are bought in England, and the time at which the furs are sold in England which have been procured by bartering those goods—so extremely slow and tedious are all the operations in the wide-spreading and thinly-inhabited territories of the company. It is undisputed, however, that the company's profits from the fur-trade are quite out of the line of ordinary commercial transactions; and if the statements of many writers on the subject are to be received as correct, the profits are quite enormous. Lieutenant Chappel, some years ago, estimated the profits at 2000 per cent. The Rev. C. G. Nicholay, in his 'Oregon Territory,' says, "A fourpenny comb will barter for a bear's skin worth 2*l.*" Dr. King; in his 'Arctic Narrative,' says, "A coarse knife, worth, all expenses included, no more than sixpence, is bartered for three marten skins, worth in London five guineas; and for the skin of the black sea otter, worth fifty guineas, the natives obtain in exchange only goods to the value of two shillings."

It is believed by competent authorities, that even if the fur-trade were thrown open, a long time would elapse before the trading of the company would cease to hold its prominence: because of the wide ramifications of their system, and because also of the ties of various kinds which bind the native hunters to them. There are not many furs procured from Vancouver.

Concerning the quantity of furs and skins brought to England, the official returns are not quite clear, seeing that sheep and goat skins are combined in the same entries as those which we are more in the habit of denominating furs. The Hudson's Bay Company, during the last five years, have imported about 700,000 skins annually. Only a small number are sold for consumption in England; the greater part is bought up by foreign merchants, who come to London for that purpose; or rather, they are purchased and partially prepared in England, and then sold to foreigners, especially the merchants of Leipsic. Our total imports from all quarters nearly reach 4,000,000 skins annually, of which 400,000 are racoon and 600,000 seal; the greater portion of the remainder comprises weasel, marten, beaver, neutria, musk-rat, rabbit, and squirrel skins. It is roundly estimated that the *retail* value of all the furs put to use annually in all parts of the world cannot be much less than 7,000,000*l.*, of which one-third is produced by Russia.

Taking one particular year, 1856, we may usefully, in addition to the number of furs imported, quote the average prices assigned by the importers in computing the real values.

	No.		Average Price.
Bear	11,870		£2 4 0
Beaver . . .	82,830		0 9 6
Coney . . .	142,285		0 0 4
Ermine . . .	96,523		0 1 1
Fitch	158,955		0 2 8
Fox . . .	81,487		0 11 10
Lynx	15,688		0 13 0
Marten . . .	206,777		0 12 0
Minx	112,466		0 7 9
Musquash . .	1,190,430		0 1 2
Neutria . . .	175,821		0 12 0
Otter . . .	19,930		2 0 0
Racoon . . .	490,128		0 4 0
Sable . . .	844		2 10 0
Seal	681,234	(about)	0 5 0
Squirrel . . .	2,188,737		0 0 4

FUSCOBALTIA. [Cobalt, *ammoniacal compounds of cobalt.*]

FUSE is a tube filled with a peculiar combustible composition. Fuses are principally used in firing shells. They are made in such a manner, that either by cutting or boring, or adjusting as in the fuse used in Sir W. Armstrong's gun, the length of the composition may be proportioned to the intended range of the shell, so as to burst the shell when it strikes the object, or before if required. The common wooden fuse is made of well-seasoned beech-wood in the form of a slightly tapering cylinder, with an enlargement at the larger end. The cylinder is pierced by a bore of ¼ inch in diameter, which terminates in a hemispherical cup in the enlargement. The bore is *driven* with fuse composition consisting of nitre, 3 lbs. 4 oz.; sulphur, 1 lb.; mealed powder, 1 lb. 12 oz.; which is hammered in hard by the hand, and then burns at the rate of ·2 inches per second. The cup is primed with quick match, in order to be easily ignited by the explosion of the shell. The exterior of the wooden cylinder is marked with rings ¼ inch apart, so that by sawing off a piece or by boring out the composition from the lower end it can be made of any length required; the fuse is then fixed in the shell by gently hammering it in. For sea service metal fuses are employed. They are made of gun-metal of the same shape as the wooden ones, but are screwed into the shell, which is fitted with a gun-metal collar to receive them. They cannot be cut or bored to any particular length, as it is not considered safe to do so on board ship, but are made of three lengths, 4, 3, and 1½ inches, which burn 20, 7½, and 2 seconds. The priming is protected by a metal cap which is unscrewed when required.

The old wooden fuse has been nearly superseded by one invented by Captain Boxer, R. A. a few years ago. The external form is much the same, but the bore is slightly eccentric, and parallel to it; two much smaller bores or channels are made in the thicker side of the wood. These small bores contain quick match, and fine grain powder, which communicate with the fuse composition at the bottom. Small holes ·2 inches apart are made from the exterior to the bore containing the quick match and fine grain powder, and are filled up again with putty. By boring through the putty and the wood between the channel containing the fine grain powder and the fuse composition, these two are put in communication as it were, and when the composition has burned down to that point in the fuse, the flame drives through the hole, lights the powder and the charge of the shell at once. The small holes are bored at ·2 of an inch apart, those in one row being opposite the blanks of the next, so that the fuse can be adjusted to tenths of an inch, with much greater ease and precision than with the old fuse. Boxer's fuse also has the advantage of being solid at the end, the bore with composition not running the whole length, hence there is no chance of the composition being driven through by the concussion of the discharge. Sir W. Armstrong, by a very beautiful arrangement, which it would take too long to describe here, has made his fuse so that without removing it from the shell, by turning a dial-marked plate at the top which carries the composition in a circular ring, any portion of this ring is brought opposite a channel of fine grained powder, which communicates with and fires the charge of the shell.

FUSEE. [Horology.]

FUSEL OIL. The oils which contaminate potato and grain spirit are classed by the Germans under the common name *fuseloel*, and the same term translated is applied by English chemists to these oils. Potato spirit is accompanied by the hydrated oxide of amyl, or oil of potato spirit [Amyl], whilst grain spirit is accompanied by an oily matter consisting of margaric, capric, and œnanthic acids, which probably, with the spirit, form their corresponding ethers. Dr. Gregory suggests that this is probably the composition of the oil of grain, the *Oleum siticum* of Professor Mulder.

FUSIBLE METAL. An alloy of 5 parts of bismuth, 2 of tin, and 3 of lead, melting about the temperature of boiling water. It is used for stereotype plates, and for the blocks of calico printers. [Bismuth].

FUSION. The different temperatures at which certain solids are rendered fluid have been already mentioned. [Freezing Points.] In addition it may be merely remarked that fusion is sometimes used with the prefix of *watery*, and at other times *igneous*. Watery fusion is that which occurs when a salt, such as sulphate of soda for example, containing much water of crystallisation, fuses or melts in its water by exposure to a moderate heat; it may afterwards undergo igneous fusion by exposure to a much higher temperature.

FUSTIAN is a kind of cotton fabric similar in the mode of manufacture to velvet, having in addition to the warp and weft common to all woven goods, a *pile* consisting of other threads doubled under the weft, and thrown at intervals so close together that when the goods are finished the interlacing of the warp and weft are concealed by them. [Velvet.] While in the loom the pile forms a series of loops, which are afterwards cut and sheared. The cutting is performed by running a knife through each series of loops as they occur in the weft; this gives an uneven and hairy appearance to the cloth, which is afterwards remedied first by the shearing process, and afterwards by singeing and brushing—which latter operations are repeated until the fustian has acquired a smooth and polished appearance. The shearing of fustians is a separate art, employing many thousand persons in Lancashire. Until lately the operation of fustian-cutting was conducted by hand; but the aid of machinery has now been obtained; and instead of the tedious operation of cutting open only one set of loops at once, a series of knives are brought to act together and continuously, until the whole piece is finished. By this means the work is not only done more quickly, but is also better performed than when its excellence depended upon the uniform precision of the human hand.

Various kinds of fustians are made, and are known by different names, according to their form and fineness. The best kinds are known as cotton velvet and velveteen; besides these there are beaverteens, moleskin, corduroy, and cords. Different patterns are produced by different dispositions of the pile threads. Fustians are woven both in the hand-loom and with the power-loom; they are made of different widths, some pieces being 18 and others 27 inches wide: a piece of velveteen of medium quality, 90 yards long and 18 inches wide, weighs about 24 or 25 lbs. The yarn for the warp is made of New Orleans cotton, or of Upland Georgia and Brazil cotton mixed, of the fineness of 32 hanks to the pound; the weft and pile are usually spun from Upland mixed with East India cotton, and the yarn is commonly of the fineness of 24 hanks to the pound. For further illustrations, see Cotton Manufacture; Velvet; Weaving.

FUSTIN. The non-azotised yellow colouring matter of fustic. Its composition is not known.

FUTURE. [Conjugation; Time.]

G

G. This letter is derived from the Latin alphabet, in which it first appears. In the Greek alphabet its place is supplied by *zeta*. If, as seems probable, the sound of this Greek letter was the same as the consonantal sound at the beginning of the word *judge* (see Z), it may perhaps be inferred that the hissing sound now given to the letter *g* existed already in some dialect of ancient Italy. The sound at any rate is familiar to the modern Italian. The sound of the letter *g* in the English language is two-fold. Before *a*, *o*, and *u*, and occasionally before *i* and *e*, it is the medial letter of the guttural order. The other sound, which it possesses only before *i* and *e*, is one of the medials of the sibilant series, and is also represented by the letter *j* as pronounced by the English. [ALPHABET, col. 234.] The sibilant sound is written in Italian by two letters, *gi*, as Giacomo, Jacob, or by *gg*, as *oggi*, to-day. The two-fold nature of the sound corresponds to the double sound of the letter *c*, which is sometimes a *k*, sometimes an *s*. [See C.]

The guttural *g* is liable to many changes in different dialects or languages.

1. *g* and *k* are convertible. Thus the Greek and Latin forms genu, *γονυ*; gen, *γεν*, as seen in gen-us, *γεν-ες*, *gi-g(e)n-o*, *γι-γ(ε)ν-ομαι*; *gnosc*, as seen in *gnosc-o*, *γι-γνωσκ-ω*—severally correspond to the German and English *knie*, *knee*: *kind*, *kin*.

2. *g* and an aspirated guttural: as, Greek, *χην*; German, *gans*; English, *goose* and *gander*. Perhaps *χαινω* may be related to the German *gaffen* and English *gape*. There can be no doubt as to the connection between the Greek *χθες*, the Latin *hes-ternus*, and the German *ges-tern*. The close connection of the two sounds may also be seen in the pronunciation of the final *g* in high German like *ch*, as *Ludwig*, &c.

3. *g* and *h*. As the letter *h*, when pronounced at all, is only a weak aspirate, this interchange strictly belongs to the last head. As an additional example, we may refer to the Latin word *gallus*, which has all the appearance of being a diminutive, like *bellus*, *ullus*, *asellus*, from *benus*, *unus*, *asinus*. If this be admitted, the primitive was probably *ganus*; and we see its corresponding form in the German *hahn*, a cock.

4. *g* often disappears: First, at the beginning of a word, as in the Latin *anser*, a goose, compared with the forms given above, and in the English *enough* compared with the German *genug*. A large number of examples of this may be seen in the poetical participles of the English language, commencing with a *y*, as *yclept*, *yclad*, &c.; also in *ago* for *agone*; in all of which the fuller form began with *ge*, as is still seen in German. The loss of *g* is particularly common before *l* and *n*, as Eng. *like*, Germ. *gleich*; Lat. *nosco*, *nascor*, *nitor*, from *gnosco*, *gnascor*, *gnitor*. Secondly, in the middle of words between vowels. This may be seen in French words derived from the Latin, as: *legere*, *lire*, read; *magister*, *maistre*, master; *Ligeris*, *Loire*, &c.; also in English words connected with German, as *nagel*, *nail*; *segel*, *sail*; *regen*, *rain*, &c. In such cases the vowel is generally lengthened. Lastly, at the end of words, as, *sag-en*, *say*: *mag*, *may*; *tag*, *day*; here again the syllable is strengthened.

5. *g* and *y* are convertible; as, *yester-day*, compared with the Germ. *gestern*; *yawn* with *gähn-en*; *yellow* with *gelb*. In our own language we find related words showing this difference: *yard* and *garden*; *yate*, a dialectic variety of *gate*; *yave* for *gave* (Percy's 'Reliques,' i. p. 294, note); and *yode*, a perfect of *to go* (Glossary of same).

6. *g* is convertible with *gu* and *w*. In the Latin language there co-exist the forms *tinguo*, *tingo*; *unguo*, *ungo*; *urgueo*, *urgeo*, &c. In the French language *gu* is presented to the eye, but *g* to the ear, in the following: *guerre*, *guêpe*, *guarder*, &c.; while in English we have *war*, *wasp*, *ward*, or *guard*. Under this head it may be observed, first, that a final *w* in the English language often corresponds to a guttural in other Teutonic dialects, as *saw*, *raw*, *crow*, *row*, *maw*, &c.; secondly, that we often have two letters, *ow*, where the German has a guttural g, as *follow*, *sorrow*, *morrow*, *furrow*, *gallows*, *marrow*, *borrow*, *barrow*.

7. *g* and *b* interchangeable. This is generally confined to those cases at the beginning of words, when an *r* or *l* follows, as in the Æolic forms, *γλεφαρον*, *γληχων*, *γαλανος*, in place of *βλεφαρον*, *βληχων*, *βαλανος*. Hence the Latin *glans*. So the Turks have given to Prussia the name of *Gharandaberk*, that is, *Brandenburg*. This change of a guttural to a labial is more intelligible, where a syllable originally commencing with such letters as *gu* or *gou* has subsequently appended to it a syllable which contains a weak vowel, *e* or *i*. By such addition there is produced the vowel assimilation which the Germans call *umlaut*, but at the same time a small remnant of the original vowel-sound is retained in the form *w*. Thus *gouz-out* in Breton is an infinitive signifying to know, connaître. The suffix of the first person of the future is *inn*, the effect of which is to modify the base *gouz*, so as to produce the form, *gwéz-inn*, je connaîtrai, and in a compound, *ana-véz-inn*, je reconnaîtrai. Here the *g* wholly disappears, and we have in its place a lip-letter *v*. Such a change is of repeated occurrence in Breton: and it is on this account that our example has been taken from this outlying language. We have, however, an example of a similar influence in English, where *good*, Germ. *gut*, on receiving the comparatival suffix *er* passes through some such form as *gwetter*, and becomes eventually *better*.

8. *g* and *d*: as *δη-μητηρ* for *γη-μητηρ*. Examples of this interchange may be heard from the mouth of nearly every child in its first attempts to speak, as *Dy Flot* for *Guy Fawkes*, *dood boy*, *do away*, &c. This change, as in the last case, is common before *l*; hence the Latin *dulcis* by the side of the Greek *γλυκυς*.

9. The guttural *g* and the sibilant *g*. It was stated in C that the hard sound of that letter in the Western languages of Europe often corresponded to a hissing sound in the Eastern. So too the hard *g* belongs to Europe, the *j* sound to Asia. Thus *rey*, a king, is in the East *rajah*.

10. The sibilant *g* and *di* or *bi* before a vowel. For examples, see D and B.

GABION. A hollow cylindrical basket open at both ends. They were formerly made of different dimensions, according to the service for which they were to be employed; they are now, however, all made of one size in the British service, namely, 2 feet in diameter (exterior), and 2 feet 9 inches high in the wicker-work. They are constructed in the following manner:—A circle of 22 inches in diameter is traced on the ground, each quarter of this circle is divided into 4 or 5 parts, according to the suppleness or stiffness of the *withes* to be used in *wailing* this basket work; at each of these points upright pickets 3 feet 6 inches in length are driven. The wicker-work which then follows may be either performed with two rods, called *pairing*, or with three or more, called *wailing*; all that is requisite is that each rod should be successively twisted over and outside those before it, passing as many pickets or stakes as there are rods to be waled, before being brought inside. Fresh rods are introduced as fast as each rod used in wailing comes to an end, and they should not be all of one length to terminate together; each layer is hammered down tight on the one preceding. When the wicker-work has risen to the height of 2 feet 9 inches, the whole is stitched together with rope yarn or twisted withes, the gabion pulled up and the pickets cut off and pointed at a length of 3 inches on each side beyond the wicker-work. Gabions are used in the revetment of field works, SAPS, PARAPETS, BATTERIES, &c.; they are then placed on end, the earth from the excavation thrown into them, when they act as a *retaining* wall to the earth which is thrown over and in front of them. When the height of the parapet requires it, two rows of gabions are placed one over the other, generally with a line of fascines between, the whole being terminated with three rows of fascines placed pyramidally, that is, two as a base and one at top, the revetment having a slope of 3 inches in 2 feet to the front. The weight of a gabion varies much according to the density of the wood from 20 to 40 lbs., and upwards; in fact, like many other points in military art, this requires great forethought. In the West Indies, after gabions had been made of the usual size for the attack of a post, they were found so heavy that it was impossible to carry them.

There is another description of gabion termed *sap roller*, used in sapping. The sap roller consists of two gabions each 6 feet long, the larger one 4 feet in diameter, the smaller 2 feet 8 inches, both strongly made, fastened together, the smaller inside the larger, and the interval filled with faggots or pickets of strong wood, so as to be musket proof. This is used in pushing on in front of a sap as a mantlet. [SAP.]

During the siege of Sebastopol it was found difficult to procure brushwood to make gabions, and Major Elphinstone, R.E., proposed using the iron hay-bands (hoop iron) employed in packing the compressed hay instead of the withes; these were tried and found of great service, not so liable to be destroyed by the explosion of guns when used in the revetment of embrasures, &c. Since then this idea has been further developed by Captain Tyler, R.E., whose gabion has been adopted to a certain extent in the service. This gabion consists of a plate of thin galvanised iron, which, when required to serve as a gabion, is formed into a cylinder by being sewn together by eyes provided for the purpose at its edges, but which, from lying flat, is easily carried. It is doubtful, however, whether a square gabion of sheet iron would not answer all purposes better.

GABLE, the triangular upper part of the end wall of a building, corresponding to the sloping sides of the roof which terminates in it. The acuteness of the angle depends therefore on the pitch of the roof, and differs considerably in different examples. Formerly the entire end of the building of which the gable is a part was not uncommonly termed the gable, but it is now more commonly called the gable-end. The term gable is not used in classical architecture, the place of the gable being occupied by the pediment. In Elizabethan domestic architecture, the open ornamental terminations of projecting wings, &c. are called gables, though they have no connection with the roof; false gables are not uncommon in Italian ecclesiastical architecture.

In ecclesiastical architecture of the Romanesque and pointed Gothic periods the gables are very important features. In our own country, church gables of the Norman and Early English periods are usually finished with a flat or moulded coping at the sides; and frequently terminated with a cross or finial at the apex. Sometimes in rich Early English and Decorated examples crockets are carried up the coping. Gables of Decorated and Perpendicular date, sometimes have a parapet, either plain, pierced, panelled, or battlemented. In old English secular architecture also, the gable was made a highly decorative feature either constructively or by the addition of ornamental barge-boards. [BARGE-BOARD.] Numerous examples of all the kinds of gables here referred to will be found in Messrs. Brandon's 'Parish Churches,' and Paley's 'Ornamental Gables.' For examples of some of the many varieties of Elizabethan gables see ELIZABETHAN ARCHITECTURE. In some English houses of the time of Elizabeth and James I., and commonly in old Scottish and continental buildings (especially those of Flanders, Holland, and Germany) the sides of gables are formed like a series of steps: these are known as *stepped-gables*, in Scotland they are termed *corbie-steps*. The small gable-like ornaments over niches, on buttresses, &c., in Gothic architecture are called *Gablets*: see examples under BUTTRESS, col. 472.

GADUIN. A brown matter said to be contained in cod-liver oil. Its composition is unknown, and its existence as a distinct compound very doubtful.

GAEL, GAELIC. Although the language spoken by the Scottish Highlanders is familiarly known among the Lowlanders by the name of the *Erse*, or, according to the more usual pronunciation, the *Ersh*,—that is, plainly, the Eirish or Irish,—the people themselves are never called by that name. Among the Highlanders the name Erse is unknown, either as that of the nation or of the language. They call themselves only the *Gadhel*, also sometimes written and always pronounced *Gael*; and their language the *Gaedheilg*, pronounced *Gaeilg*, or, nearly, *Gaelic*. The name *Gaelic* is also in familiar use among the Lowlanders as that of the language. Further, the only name by which the Irish are known to the Scottish Highlanders is *Gael*; the latter call themselves *Gael Albinnich*, or the Gael of Albin, and the Irish *Gael Erinnich*, or the Gael of Erin. The Irish also call themselves the *Gadhel*, or *Gael*; and their language the *Gaelic*. Finally, the Welsh call the Irish *Gwyddel*, which is evidently the same word with *Gadhel*, or *Gael*.

This is nearly all that can be stated as matter of fact in regard to the name *Gael*. The rest is all speculation and conjecture; of that, however, few words have given rise to so much. We shall not here attempt to do more than to indicate and arrange the various points as to which many volumes of philological and historical controversy have been written.

It has been generally assumed and admitted that the modern Gael are a portion of the *Galli*, or Gauls, of antiquity, the people who gave its former name to the country now called France, and who were principally, though by no means exclusively, known to the Greeks and Romans as the inhabitants of that region. This opinion has been adopted upon the grounds of the similarity of the two names,—some historical and traditional testimony to the fact that South Britain was originally peopled from Gaul,—some traces, rather faint and disputable, of identity of institutions and customs,—and, what would be the strongest argument, if it were well made out, the evidences of identity of language conceived to be established by the comparison of the names of places in France, and a few other remains of the old language spoken there, with the modern Gaelic of Scotland and Ireland. The Rev. Archdeacon Williams, in an essay printed in the 'Transactions of the Royal Society of Edinburgh,' vol. xiii., has been the strongest supporter of this theory, and maintains that the Galli Veteres, or Umbrians, of the Romans, the inhabitants of Gallia Cisalpina, were of the Cumic or Cymric races; that their language "formed some portion of the non-Hellenic elements of the Latin tongue; that the race was cognate with the Cymri of Wales, and that they were Celts, and not Germans."

Supposing the Gael to be the *Galli* of the Roman writers, and the *Galatai* (Γάλαται), or *Keltai* (Κελται), of the Greeks, sometimes spoken of by the ancients as a general name for the Gauls, sometimes as the name of only a certain portion of the Gauls, the question arises, whence did the Gaels of Ireland, Scotland, and Wales derive their origin? A tradition exists that Ireland was colonised from Spain, where Celtic tribes certainly existed, and that the Highlands of Scotland were peopled from Ireland. This is not improbable; and Wales might have received the stock from the coast of France. This would account for the variations of the dialects. Diefenbach ('Sprachliche Documente zur Geschichte der Kelten') conjectures Galloway and Northumberland to have received the Celtic element from Ireland, and concludes that the Picts were the sea-rovers of Scandinavia. See also Zeuss's 'Grammatica Celtica e monument vetustistam Hibernicae ling. quam Britannicae Dialecti Cambricae, Cornicæ, Armoricae, nec non e Gallicae priscae reliquiis construxit,' Leipsic, 1853, as well as J. von Görres, 'Die drei Grund-Wurzeln des Celtischen Stammes in Gallien und ihre Einwanderung.' Munich, 1845–6.

There has been a world of controversy, also, about the origin and meaning of both *Gael* and *Celt* (anciently, it is to be remembered, pronounced *Kelt*); the confusion here again being increased by the difference of opinion as to whether these are different words or only different forms of the same word. The Greek *Galatai* and *Keltai*, the Latin *Galli*, the *Gael* of the Scotch and Irish, and the *Galles* of the French for Wales, seem all but variations of the same word. It is hardly necessary to enter into the meanings which the words *Gael* and *Celt* bear in the ancient Gaelic language, though they have caused much discussion.

It would occupy much more space than we can afford to enumerate even the more important works in which these various controverted points have been discussed in our own and other languages. We shall only mention 'The Highlanders of Scotland, their Origin, History, and Antiquities,' by W. F. Skene, 2 vols., 8vo, London, 1837, being an essay to which a prize had been awarded by the Highland Society of London. Mr. Skene's views and reasonings are of considerable ingenuity; but whatever may be thought of the part of it which relates to the origin of the Gael, the work is an important contribution to early Scottish history. The essay by the Rev. Archdeacon Williams, 'On One Source of the Non-Hellenic Portion of the Latin Language,' printed in vol. xiii. of the 'Transactions of the Royal Society of Edinburgh,' read in March, 1836, has much ingenious argument and learning in support of the theory we have already mentioned.

GAGE or GAUGE, any apparatus for measuring the state of a phenomenon. But the term is usually restricted to some particular instruments, such as the gage of the air-pump, which points out the degree of exhaustion in the receiver; the *steam-gage*, for measuring the pressure of steam; and the *gas-gage* for that of gas; also the *wind-gage* [ANEMOMETER], the *tide-gage*, &c., all of which are mentioned in connection with their several subjects. There are also various gages used in certain trades and manufactures, such as the *rod-iron gage*, the *nail-rod gage*, the *button maker's gage*; others are used in *watch-work*; there are also the *gun-maker's gage*, and gages for measuring wires and sheet metals. These generally consist of thick plates of steel of several sizes and forms, around and near the edges of which holes are drilled, with a notch leading from the edge into each hole. There is no system in the gages in common use, so that much confusion arises in attempting to reduce the measure to a common standard. Thus, the Birmingham gage for iron-wire, sheet-iron, and steel, differs from that used for sheet-brass, gold, silver, &c., and both these differ from the Lancashire gage for round steel wire. To render the confusion worse, gages nominally of the same value are made by different manufacturers without sufficiently agreeing as to the unity of measure.

To avoid these inconveniences, our best tool makers have long advocated the adoption of a uniform scale. Mr. Holtzapffel, in the appendix to the second volume of his 'Mechanical Manipulation,' proposes to employ only the decimal divisions of the inch, and those under their true appellations only. The division of the inch into a hundred parts would be sufficiently minute; and the measures 1, 2, 5, 10, 50, &c. hundreds would be sufficiently impressive on the mind. It does not follow that the entire hundred notches should be used; as in the greater thicknesses of wire and sheet metal the gradations from one size to another are not so minute as in those of the thinner kind. In the measurement of precious metal, where a hundredth of an inch might be too much, either there might be half-degrees or numbers, or a finer scale might be adopted below one-tenth of an inch. Holtzapffel enumerates the following advantages as likely to result from the use of such a decimal scale for denoting the thickness of wires, sheets, plates, &c.:—It would introduce a system which would be easily and *equally* known to all whom it might concern, and who would all interpret it in the same sense. It would facilitate the employing of verbal and written instructions, by lessening the chances of mistake or misinterpretation. It would render very easy the proportioning of various magnitudes so as to form a series. It would enable quantities to be written down more easily and accurately than at present. It would facilitate the comparison of one size with another; seeing that in vulgar fractions each has a *specific* relation to the unit, whereas in decimal fractions all have a *general* relation in common. It would bring all foreign measures within more easy reach of our knowledge. It would allow the exact weight in every superficial foot of sheet metals and other substances to be readily arrived at, by taking the specific gravity as the other element in the calculation. Lastly it would furnish constant multipliers for determining, from the specific gravities of substances, the exact thicknesses of plates or sheets of the same which shall precisely weigh one ounce or one pound, troy or avoirdupois. The graduation into hundredths being effected, the nomenclatures would follow easily; let a wire one-tenth of an inch in diameter, or a plate or sheet one-tenth of an inch thick, be called No. 10, and so on for other dimensions: there will then be swept away a large amount of confusion which now besets our factories and workshops.

Nearly related to this subject is Mr. Whitworth's exquisite contrivance for gaging or measuring minute quantities. In the Proceedings of the Institution of Mechanical Engineers, for 1859, an account of this remarkable machine is given; showing it to be the most accurate measuring apparatus yet devised. Newton's colures of thin plates, interpreted by formulæ of later introduction, show that a millionth of an inch is an appreciable quantity in relation to the breadth of waves of light; but Mr. Whitworth is the first who has felt justified in dealing with such extremely minute quantities as being measurable by strictly mechanical means. He can measure the relative lengths of two small pieces of steel, of which one exceeds the other by not more than *one millionth of an inch*. Nay, he feels confident of being able to test even one-half of this minute quantity. If we touch a piece of cold metal for an instant with the fingers, it expands by the increase of heat and the amount of this expansion we can measure. If the bar be a yard long, the touch even by a finger-nail is sufficient to produce an elongation which his machine can determine. The mechanism by which the astonishing result is produced mainly consists of exquisitely cut screws with graduated nuts or heads. At present, this is rather a scientific than a manufacturing agent; but Mr. Whitworth has succeeded in bringing into use new gages for wire-drawers and the manufacturers of sheet metal, in which the thousandth of an inch is an admitted and practicable element. Gages are now made, having decimal numbers on one side from No. 18 to No. 300, measuring from ·018 to ·300 of an inch. It will be for the manufacturers to decide how many thousandths of an inch there shall be in any particular sheet or wire; but this point once determined, Mr. Whitworth's gage will enable them to measure it. He observes, "I consider that for the shop the use of standard gages is better than any measuring machine, on account of the difficulty of using a sufficiently delicate instrument in regular shop-work, and the greater liability there would be to alteration in the standard both of diameter and length."

GALATIANS, ST. PAUL'S EPISTLE TO THE, one of the canonical books of the New Testament. Its authenticity has never been doubted: it was frequently cited by the apostolical and succeeding fathers (Lardner's 'Credibility of the Gosp. History,' vol. ii.), and was admitted by Marcion to a place among the apostolical writings. The date of this epistle is much disputed, some critics supposing it to have been written as early as A.D. 48, and others as late as 58. Two journeys of St. Paul to Galatia are mentioned in the Acts; one in A.D. 50 (Acts xvi. 6); and the other in 55 (Acts xviii. 23). It must have been written shortly after one of these visits, since St. Paul complains (i. 6) "that they were so *soon* removed from him that called them into the gospel of Christ unto another gospel." Michaelis, 'Introduction,' vol. iv., contends that it was written soon after the first visit, which took place probably about A.D. 49 or 50. But in chap. iv. 13, St. Paul himself says, "Ye know how through infirmity of the flesh I preached the gospel unto you *at the first* (τὸ πρότερον)," which proves that the apostle had visited them twice; and thus we may conclude that it was written after the second visit, or about A.D. 56 or 57, an opinion coincided in by the great majority of critical authorities. It is stated at the conclusion to have been written from Rome, but this is probably incorrect, though Michaelis and others support it.

It appears that shortly after St. Paul had left Galatia, some Judaising teachers had effected a great change in the churches of that country by teaching the Gentile converts that it was necessary for them to observe the ceremonial law, and submit to the rite of circumcision. They alleged that the other apostles taught this doctrine, and that St. Paul alone differed from them. They argued that the Galatians ought not to rely upon the authority of St. Paul, since he was not an apostle. These individuals were so successful that some of the Galatians appeared to have submitted to circumcision. To counteract these errors St. Paul wrote this epistle, in which he maintains that the authority of the other apostles could not be quoted as superior to his own, since he had received his apostleship from Christ himself, and had on this very subject "withstood Peter to the face, because he was to be blamed." (i. ii.) After thus vindicating his apostolical dignity, he argues in the remaining part of the epistle that the law had only been intended as a preparation for Christianity, as a "schoolmaster to bring men unto Christ, that they might be justified by faith," and that those who considered the observance of the Jewish law as necessary for salvation deprived themselves of the blessings of the Gospel. He concludes by exhorting them not to use the liberty which the Gospel gave them "for an occasion to the flesh, but by love to serve one another." On the undesigned coincidences with the 'Acts,' see Paley's 'Horæ Paulinæ.' The number of commentaries on this Epistle have been very numerous, in Latin, German, French, and English. One by Luther is still highly esteemed.

GALAXY. [MILKY WAY.]

GALENA. [LEAD, *Sulphide of.*]

GALILEE, in ecclesiastical architecture. In mediæval churches a portion of the western end of the church was frequently parted off from the rest and appropriated to strangers or those not numbered among the faithful. This was termed the Galilee, in allusion, as is supposed, to the scriptural "Galilee of the Gentiles." Sometimes in cathedrals it was an entrance porch, as at Ely and Lincoln; sometimes, as at Durham, a large chapel at the west end of the nave: see the plan of Durham Cathedral under CHURCH. It is said that this Galilee was built for the use of females, who were prohibited passing beyond the north porch in Durham Cathedral. In some parish churches a portion of the western end of the nave was marked off by a step or line of division, and called the Galilee.

GALIPEA. (*Materia Medica.*) The genuine Angostura or cusparia bark is obtained from a species of this genus, but whether from the *G. cusparia*, as stated by Humboldt, or from a distinct species, *G. officinalis*, as asserted by Dr. Hancock, is not determined. Angostura bark is obtained both from the stem and branches; the specimens from the stem are flat, from 2 to 3 lines thick, while those from the branches are often quilled, and from ½ to 1 line thick. The pieces are sometimes from 6 to 15 inches, but more frequently only from 2 to 6 inches long, and from ½ to 2 inches broad. Some specimens have the surface covered with a thick, fungus-like, whitish-yellow or clay-coloured crust, which may be more or less easily scraped off, and beneath which is a yellowish-red smooth bark, often exhibiting small cracks. Other specimens have this covering much thinner and closely adhering to the bark. The internal surface is generally smooth, of a tawny or reddish-yellow colour.

The bark is easily broken, and the recent fracture is of a brownish-red colour, smooth, with a resiny shining surface. The shining appearance is best seen when a transverse section is made with a sharp knife. The smell is disagreeable: the taste pleasantly bitter, warm, aromatic, and causing a flow of saliva. The powder has the colour of rhubarb. The infusion is of an orange-yellow colour; the decoction a clear light brown.

Brandes thought that he had discovered an alkaloid, which he proposed to call Angosturin, but it has not been detected by subsequent chemists. This bark contains neither gallic acid nor tannin. According to the analysis of Fischer it consists of—

Volatile oil (of an acrid nature)	0·3
Bitter hard resin	1·7
Balsamic soft resin	1·9
Elastic resin	0·2
Bitter matter (Angosturin bitter)	3·7
Gum	5·7
Woody fibre	89·1
	102·6

So minute an account of this substance would not be necessary, were not the true Angostura bark liable to be confounded with the false, which possesses such poisonous properties that very fatal consequences have resulted from the substitution of the one for the other. It has been ascertained beyond any doubt, that the false Angostura bark which comes from the East Indies, is the bark of the Strychnos nux vomica. But even in Calcutta this false bark is confounded with *rohuna*, the harmless bark of *Soymida febrifuga*. [SOYMIDA.]

False Angostura bark was first observed in 1804 by Dr. Rambuch, of Hamburg, by poisonous effects following the use of a decoction of the bark; and similar consequences having been observed at Vienna, the Austrian government ordered all the Angostura bark in the empire, genuine as well as false, to be burnt, and interdicted its future importation. The Russian and Würtemburg authorities made known the danger, and published the marks of distinction, which are sufficiently characterised, and to prevent accidents, may be here enumerated.

GENUINE.	SPURIOUS.
Pieces 2 to 4 inches long; from ½ to 2 inches broad; from ½ to ¾ of a line thick.	Pieces of greater breadth than length; thickness never less than a line, often two lines.
Epidermis having on it a number of different lichens (often as many as 40 species), and a yellow membranous crust.	Epidermis generally clear (but sometimes undergoing a peculiar transformation), and seldom having any, or not more than two lichens (*Opegrapha Pelleticri*, and *Pyrenula nitida*). A species of chiodecton has been supposed to be found on it, but this appearance arises from an alteration of the epidermis.
The incrustation spongy and insipid, and not changing colour by the action of nitric acid.	The crust has the general properties of the bark, and assumes a deep green by the action of nitric acid. It contains a resinous colouring principle, Strychnochromin.
Crust easily removed by the nail.	Crust not easily removed.
Inner surface yellow, and separable into layers.	Inner surface brown, or even black, not separable into layers.
Texture not close, weight light, easily broken, fracture even, shining, and resinous. Cuts transversely without difficulty.	Texture compact, heavy, not easily broken, fracture even, but not shining or resinous, exhibiting two layers. Very difficult to cut.
Placed in water it soon imbibes it, and becomes soft.	Scarcely softens in water.
Smell strong and disagreeable.	No smell.
Taste an aromatic and enduring bitter, but not at all disgustingly bitter.	Taste in the highest degree disgustingly bitter; very durable, and not at all aromatic or astringent.

Spurious Angostura bark, in the dose of eight grains, killed a dog in two hours; ten grains killed a young dog in a few minutes. A very small glassful of an infusion endangered the life of an adult, while a dose of the decoction destroyed a child with acute suffering. Ether and laudanum seem to act as antidotes. Oil of turpentine may be used, but vinegar must be avoided. The dread of similar casualties from the employment of the spurious instead of the genuine Angostura bark, has prevented the use of the latter to that extent which it merits. In the treatment of the bilious diarrhœa, frequent in damp autumns in this country, after proper evacuants, it is of the most decided utility. In common English cholera likewise, and slighter cases of Asiatic cholera, it is the most beneficial agent which can be resorted to. It is best given in the form of infusion, and may either be administered alone, or with the addition of dilute nitric acid and tincture of opium, which last may be discontinued after a few doses. (Abercrombie, 'On Diseases of the Stomach,' &c.)

Re-agents produce the following effects on a cold infusion of each :—

Colour of Infusion of Genuine, Orange Yellow. *Colour of Infusion of Spurious, Light Yellow.*

Cold Infusion.	Tincture of Galls.	Bi-chloride of Mercury.	Sulphuric Acid.	Protosulphate of Iron.	Perchloride of Iron.	Carbonate of Potass.
Genuine Angostura.	Yellowish precipitate.	Copious precipitate.	Very turbid.	Whitish-gray precipitate.	Yellowish brown precipitate.	Dark red colouring, with slight precipitate.
Spurious Angostura.	White precipitate.	Renders turbid only.	No action.	Green colour, slightly turbid.	Yellowish green colour.	Greenish colouring, with dirty yellow precipitate.

GALLSTONE. [Cholesterin.]

GALL-STONES. [Calculus.]

GALLAMIC ACID. [Tannic Acid.]

GALLATES. [Tannic Acid.]

GALLEON (*galoion* in French, *galen* in Spanish) was the name given to very large ships, with three or four decks, of which many were employed in the Spanish Armada in 1588. Subsequently the name became restricted to the large vessels which the court of Spain used to send at fixed periods to the coasts of Mexico and Peru, to receive on board the gold and silver bullion extracted from the mines, and bring it to Spain. Commodore Anson intercepted, and captured after a short engagement, one of these galleons on its way from Acapulco to Manilla.

GALLERY of Mine is the passage leading from the shaft or entrance of the mine to the place where the powder is deposited. [Mine, Military.]

GALLERYTHRONIC ACID. [Tannic Acid.]

GALLEY (*galère* in French, *galèra* in Italian and Spanish), a large-sized vessel propelled by oars and sails, which was much in use in the Mediterranean until the end of the 18th century. It carried two masts with lateen sails, was long and narrow, and drew but little water; it was therefore calculated for coast navigation, and for making the shore in shallow water; and by means of its oars it had a great advantage, in the dead calms so frequent in the Mediterranean, over sailing vessels, an advantage in which it has been effectually superseded by the introduction of the steam-boat. Even long before that invention the use of galleys as a naval force had been given up by France, their construction rendering them unfit for long navigation, and for encountering the waves of the ocean. The Knights of Malta, Naples, the Pope, and other Italian states, were the last to continue the use of galleys for the purpose of coping with the Barbary privateers, whose vessels, although of a similar description, were generally smaller and unable to resist the large and well-disciplined galleys of the Christian powers. The largest galleys were 166 feet long and about 32 wide, with 52 oars. The rowers, who were generally convicts or Turkish prisoners, with chains to their feet, sat on benches on the deck. The ship carried a 24-pounder and two 8-pounders. (See a description and plate of a large-sized galley in the 'Dictionnaire de Marine,' article *Galère* in the 'Encyclopédie Méthodique.')

The galleys appear to have been an imitation of the ancient triremes, and they retained the ancient names for several parts of the rigging, such as "antenna," &c. The felucca is a kind of small galley. [Felucca.] The Venetians had a sort of large galley, with a very lofty poop, called "Galeazza."

GALLIARD (*Gagliarda*, Ital.), a lively dance in three-crotchet time, which had its origin in Rome, but has fallen into disuse.

GALLIC ACID. ($3HO,C_{14}H_3O_7+2Aq.$) The well-known astringent property of various parts of plants is due to the presence of tannic or gallic acids. Gallic acid occurs in far less abundance than tannic acid. It may be extracted directly, by precipitating tannic acid from an aqueous infusion of a bark, root, &c., by means of solution of gelatine, and then evaporating the filtered liquid, which contains the gallic acid, to dryness. The residue, digested in alcohol, treated with animal charcoal and the solution allowed to evaporate spontaneously, yields the gallic acid in a crystalline state.

Gallic acid is, however, usually prepared by a kind of fermentation from the tannic acid in nut-galls. [Galls, in Nat. Hist. Div.] Powdered galls, well moistened with water, are exposed in a warm place to the action of the air for two or three months. Mould rapidly forms on the surface of the mass, and must be occasionally removed; oxygen is absorbed and carbonic acid evolved. On subsequently boiling the whole in a considerable quantity of water, gallic acid is dissolved out, and is deposited in crystals on the cooling of the liquor.

When obtained quite pure, by recrystallisation from alcohol, and the usual treatment with animal charcoal, gallic acid is obtained in long, silky, nearly colourless needles or prisms of astringent taste, but no odour. They are soluble in one hundred times their weight of cold water, but in three parts of boiling water. Alcohol dissolves them readily, ether only sparingly. A heat of from 410° to 420° Fahr. causes the decomposition of gallic acid into *pyrogallic acid* which sublimes in brilliant white crystals, and carbonic acid, which is evolved as gas. The sudden application of too high a temperature (above 480°) to gallic acid causes the evolution of water as well as carbonic acid and *metagallic acid* or *gallulmic acid* remains. Ebullition with strong solution of potash converts gallic acid into *tannomelanic acid.* Gently heating with sulphuric acid converts it into *rufigallic* acid, while nitric acid rapidly oxidises gallic acid to oxalic acid.

Gallates are formed by the union of gallic acid with bases. In this way three classes of salts result :—

Monometallic salts . . .	$MO, 2HO, C_{14}H_3O_7$
Bimetallic salts	$2MO, HO, C_{14}H_3O_7$
Trimetallic salts . . .	$3MO, C_{14}H_3O_7$

In the solid state the gallates are tolerably stable, in solution they rapidly absorb oxygen if exposed to the air and are decomposed. The characteristic reaction for the detection of gallic acid is the production of a deep bluish-black solution on the addition of a mixture of proto- and per-salts of iron.

GALLIOT, a strong-built flat-bottomed vessel of a peculiar construction, used as a bomb-ship to fire against forts or batteries on the coast. The largest are of the burden of 400 or 500 tons, and above 100 feet in length. See account and plate of the same in the 'Dictionnaire de Marine,' in the 'Encyclopédie Méthodique,' art. "Galiotte." Galliot is also a kind of small galley or large felucca, used chiefly in the Mediterranean, especially by the Barbary corsairs. [Galley.] The Dutch, Swedes, and other northern nations have a sort of merchant-ship which they call Galliot, heavy and clumsily built, but strong of timber, rounded both fore and aft, and of the burden of from 200 to 300 tons.

GALLITANNIC ACID. [Tannic Acid.]

GALLON, an old English measure of capacity. The Latin of the middle ages is *galo, galona, jalo, lagena,* &c. Dr. Bernard thinks the latter is the original. Ducange cites an old assize of David of Scotland, in which it is said the *lagena* should contain 12 lbs. of water, namely, 4 of sea water, 4 of still water, and 4 of running water. But that various gallons were used is evident from statutes of Henry III. and later kings, in which it is enacted that ale, wine, and corn shall be measured by the same gallon, containing eight troy pounds of dry wheat from the middle of the ear. These statutes produced no effect, and distinct gallons for wine, ale, and beer, and corn and dry goods, continued in use until the Act of 5 Geo. IV., c. 74, which came into operation May 1, 1825.

By statutes of 1689 and 1697, the wine gallon was declared to contain 231 cubic inches. But in 1688, by an experiment, at which Flamsteed, Halley, and others (among whom was Ward, author of the 'Young Mathematicians' Guide,' who relates the circumstance) were present, it was very distinctly proved that the sealed gallon at Guildhall (which was the *usual* standard) contained only 224 cubic inches. "However," says Ward, "for several reasons it was at that time thought convenient to continue the former supposed content of 231 cubic inches." The fact was, that the Guildhall gallon was an incorrect copy of the old Exchequer standard, placed in a more accessible locality. Previously to this, Dr. Bernard had stated his full conviction, from the measurements of predecessors whom he cites, that the said gallon contained 223·549 cubic inches; the agreement of these two experiments leaves no doubt as to their accuracy. By the Act of the 5th of Queen Anne, the wine gallon of 231 inches was made the standard; and a gallon was accordingly constructed for the Exchequer, which the committee of the House of Commons, in 1758, found to contain 231$\frac{8}{10}$ cubic inches. The account of the experiment in 1688 was preserved, and is cited by the committee.

The ale gallon was measured in 1700 or thereabouts, and found to contain 282 cubic inches. Ward imagines that this gallon was meant to bear the same relation to a pound avoirdupois which the wine gallon did to a pound troy; and 231 is to 282, very nearly as 5760 to 7000, the latter being the proportions of the two pounds. But if the wine gallon were only 224 cubic inches, then the ale gallon should have been 272¼; or, as we shall see, the corn gallon much more nearly coincides with the hypothesis.

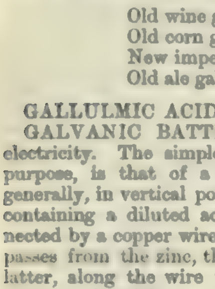
The corn gallon was thought, in the middle of the last century, to contain exactly 272¼ cubic inches. Dr. Bernard, on the same authorities, states it to have been determined at 266 cubic inches; and the statute of 1697, which declares that a round corn-bushel must be 8 inches deep and 18½ inches wide, had in fact fixed the gallon at 268$\frac{8}{10}$ cubic inches.

The imperial gallon, as settled by the Act of Geo. IV., is to contain 10 lbs. avoirdupois of distilled water, of which it is declared that 252·458 grains fill a cubic inch: consequently, the imperial gallon contains 277·274 cubic inches; being very nearly a mean between the old ale and (previously to 1697) corn gallon. According to the parliamentary standards, then, we have

Old wine gallon, 231 cubic inches.
Old corn gallon, 268·6 cubic inches.
New imperial gallon, 277·274 cubic inches.
Old ale gallon, 282 cubic inches.

GALLULMIC ACID. [GALLIC ACID.]

GALVANIC BATTERY. An apparatus for generating *current* electricity. The simplest combination which can be formed for this purpose, is that of a plate of zinc and a plate of copper placed, generally, in vertical positions and parallel to one another in a vessel containing a diluted acid, the upper edges of the metals being connected by a copper wire. In this state a current of positive electricity passes from the zinc, through the acid, to the copper, and from the latter, along the wire to the zinc: at the same time a current of negative electricity passes from the zinc, along the wire, to the copper, and from thence, through the acid, to the zinc. It is evident that the quantity of fluid furnished by a combination of this kind will be proportional to the superficies on which the acid can act; and an apparatus designated a *battery*, which may be said to consist of two plates only, one of zinc and the other of copper, was executed many years ago for the London Institution. Each plate was 50 feet long and 2 feet wide, and the two were coiled together upon a cylinder of wood, so as to leave everywhere an interval between the two metals: in that interval rope-bands of horse-hair were passed round with the coils so as to keep the metals asunder. The dilute acid was contained in a cylindrical vessel; and when the battery had to be used, the coils of metal were lowered by machinery into the vessel.



One of the earliest forms of apparatus was the *pile* of Volta, in which were combined together a considerable number of small plates of zinc and copper, alternately, with the acid between them. Under GALVANISM are explanations of the electrical action that takes place, and we here merely describe the construction of the pile. A circular plate of zinc, *z*, usually about 1½ inch diameter and $\frac{1}{10}$ inch thick, is laid upon and generally soldered to a thin plate of copper *c*, of equal diameter; and any convenient number of these are placed above one another, with the copper side undermost in all: between every two compound plates is a circular piece of paper *p*, or cloth moistened with diluted sulphuric acid; and the whole column or pile is made to preserve a vertical position by being formed within three pillars of glass or baked wood, which are connected together by having their extremities inserted in boards, of which the lower one serves as a base for the column. The paper or cloth should be rather less in diameter than the plates of metal; and no moisture should be allowed to escape over the edges of the plates.

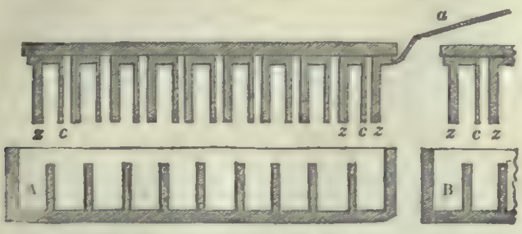
In this state the lowest plate of zinc attracts the positive electricity from the copper below it, and this continually receives a supply from the earth through the table, or the base of the pile; the quantity thus attracted is conveyed to the copper plate immediately above, through the moistened cloth, the latter serving as a conductor: again, the zinc in the second plate attracts electricity from the copper below it, and, at the same time, receives that which is transmitted to the latter from the zinc in the lowest plate. Thus the quantity of positive electricity in the zinc of the second plate becomes nearly twice as great as that which is in the lowest plate; and the process continuing, the quantity in the zinc of each plate above may be conceived to be such a multiple of that which is in the lowest plate as is expressed by the number of the compound plate from the bottom of the pile. There is consequently obtained a current of positive electricity passing upwards from the zinc, through the acid, to the copper; and if a copper wire be made to pass from the top of the uppermost zinc plate to the copper in the lowest plate, the same current will return downwards, so that a circulation of the fluid will continue till the energy of the pile is exhausted. At the same time there is a current of negative electricity passing down the pile from the copper, through the acid, to the zinc, and returning upwards along the wire.

If a second pile be formed, the plates in it may be placed in a reverse order, the copper side above and the zinc side below: if a third pile be formed, the order may be the same as in the first pile; if a fourth, the same as in the second; and so on: then, in uniting them together, a metal wire passes from the copper at the bottom of the first pile to the zinc at the bottom of the second; another wire passes from the copper at the top of the second to the zinc at the top of the third, and so on.

When a wire connects the opposite ends of one pile, or of a system of piles, the circuit is said to be *complete*: it is said to be *broken* if there are two separate wires, one proceeding from the copper at bottom, and the other from the zinc at the top. If an animal body were in connection with the farther extremities of the wires it would complete the circuit, and experience shocks.

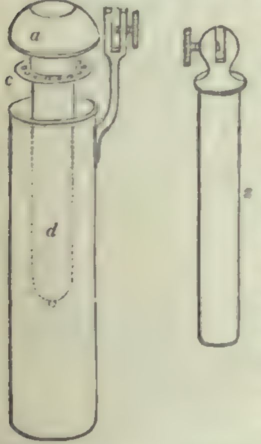
The opposite extremities of the pile, or of the wires which are in contact with them, are called the *poles* of the battery. As the current of positive electricity seems to issue from the zinc at the top of the pile, that extremity is called the *positive pole* of the battery; at the same time the negative electricity seems to issue from the copper at the bottom, and therefore the terminating copper plate is called the *negative pole*. These designations are reversed when a single pair of plates separated by an acid is mentioned. In that case, since the positive electricity passes from the zinc plate, through the acid, to the copper-plate, and the wire passes through the air from the edge of the copper to that of the zinc plate; it is evident that the positive electricity will flow from the copper, and therefore the copper is the positive pole of the combination; the negative electricity flowing at the same time along the wire, from the zinc, the latter is the negative pole. The terms *positive* and *negative* poles, as applied to the extremities of the battery, have been objected to on the ground that before connecting the two terminal wires no electricity is evolved, and when the connection is formed the electricity moves in a circuit, no portion of which is apparently more positive or more negative than another portion. Hence Faraday proposed, instead of pole, the word *electrode*, which signifies a *way*: for the negative pole *cathode*, signifying the *descending way* or *downwards*; and for the positive pole *anode*, which signifies *ascending way* or *upwards*. In forming these terms he supposed the battery to be placed on the ground with its copper or + end to the east, and the wire connecting the ends of the battery to be bent into an arc, similar to the course of the sun; in such case the electric current would flow up from the east end of the battery, and descend into it at the west end. The fluid decomposed by a current passing through it was termed an *electrolite*: the elements liberated by the decomposition were termed *ions*; those which appeared at the cathode were named *cations*, and those set free at the anode *anions*; thus in the decomposition of sulphate of copper the metal is the cation, and the acid the anion. Daniell employed the word *platinode* for the negative, and *zincode* for the positive pole; while Graham introduced the terms *zincous* and *chlorous* poles, to represent the + and −. Much of this nomenclature appears to us to be as uncouth as it is unnecessary: it was introduced at a time when the introduction of the constant battery by Daniell, and the splendid discoveries by Faraday, had somewhat unsettled the scientific mind on the subject of voltaic electricity. The new terms, with a few exceptions, have scarcely obtained a footing; which is not surprising, seeing that the old expressions *positive* and *negative poles*, and *electro-positive*, and *electro-negative bodies*, are far more simple and quite as accurate as the terms by which it is proposed to supersede them.

As the arrangement of the pile was inconvenient for experimental purposes, and, moreover, did not give much power, and the power that it did give was soon exhausted, an arrangement was introduced called the *trough battery*, of which there were many forms. The first consisted of the pile, with the plates on edge, cemented into grooves made in three sides of a wooden trough, spaces being left between every two compound plates for pouring in dilute acid, which took the place of the paper or cloth. In another form, the trough was made of glazed earthenware, by nine or more parallel partitions of the same material, which permitted no communication between one cell and another. As many pairs of plates, zinc and copper, of equal superficies, as there were partitions, were provided; the two plates of each pair were soldered or fastened together at their upper extremities, so that they might be parallel to one another, and all were united together by a rod of wood, so that they could at once be placed into or removed from the cells. The bridges or connections between the zinc and copper plates stood directly over the partitions, so that there was a copper and a zinc plate in each separate cell, except at one extremity of each trough, in which, till two troughs were connected together, the cell had only a zinc plate. When one trough was to be connected with another, in order to increase the battery, a slip of copper, as at *a*, soldered at the top of a zinc plate, was bent and made to enter the cell B, containing only a zinc plate at one end of the preceding trough. In order to form the complete circuit, one extremity of a wire was made to enter the cell A, for example, which was the positive end, and the other extremity was brought to the opposite end of the trough, or series of troughs, where it was placed in contact with the copper slip, as *a*: the positive current then flowed along the wire from the extremity first mentioned to the other.



The above form was contrived by Mr. Children; but Dr. Wollaston proposed, as an improvement upon it, to have in each cell a zinc plate between two plates of copper; for thus both surfaces of each zinc plate would become efficient in producing the electric current, and the power of the battery would be increased by one half. The battery at the Royal Institution was of Mr. Children's kind; it contained 2000 pairs of plates, each 8 inches long and 4 inches deep, and with it Sir Humphry Davy made his principal discoveries.

The battery invented by Professor Daniell consists of any number of cylindrical vessels of copper, open at the top, about 16 inches high and 3 inches in diameter, and containing a saturated solution of sulphate of copper; the exterior surface of each may be painted, but the interior, which alone is efficient in producing electricity, is made bright. On the top of the cylinder is placed a hemisphere *a* of wood, through which, in the direction of the axis of the cylinder, is a perforation above an inch in diameter; and to its base is attached a short tube *b* of copper, less in diameter than the cylinder, and carrying near its upper extremity an annular plate *c* of copper, in which are pierced several small holes. When the wooden cover is placed on the cylinder its base rests on the top of the latter; and the part of the cylinder between the short tube and the annular plate is filled with crystals or pieces of sulphate of copper, which, gradually dissolving, preserve the strength of the solution in the lower part of the cylinder.



To the interior of the short tube was affixed, in the original arrangement, one end of a piece of ox gullet *d*, about the same length as the copper cylinder, and having its lower extremity tied so that the whole formed a membranous bag; this is to contain diluted sulphuric acid (eight parts water to one of acid). A rod of zinc *z*, about the same length as the cylinder, an inch in diameter, and terminating at the upper extremity with a brass ball, is passed through the perforation in the wood, down the interior of the membrane, so that its shoulder rests on the top of the wood; the surface of the zinc being previously covered with an amalgam of mercury. Instead of a membrane, a bag of paper or canvas, or a vessel of porous earthenware, may be more conveniently used.

If now, a connection, by means of a wire or metallic rod, were made between the ball at the top of the zinc rod and the top of a stem *e* which rises from one side of the copper cylinder, the zinc will be corroded by the sulphuric acid, and the electric fluid will pass to the copper through the acid, the membrane, and the solution in the cylinder. [GALVANISM.]

The battery invented by Mr. Grove consists of several porous vessels containing strong nitric acid, and, in each, a rod or plate of platinum; each of these vessels is placed between two plates of zinc within a trough in which is diluted sulphuric or muriatic acid. The rod of platinum holds the place of the plate of copper in Children's battery, and constitutes the negative pole of each combination; the zinc plate being the positive pole. By mixing sulphuric acid with the nitric acid in the porous cells, a more uniform current is obtained. This battery is expensive, and must be placed under a chimney or a hood to carry off the nitrous fumes. For the sake of economy Bunsen uses, instead of the platinum, cylinders of carbon prepared by heating a mixture of powdered coke and caking coal, or powdered coke moistened with a strong solution of sugar. The carbon answers very well while fresh, but it soon deteriorates by absorbing the nitric acid. Poggendorf uses sheet or cast iron, which is not acted on by strong nitric acid. In Smee's battery the negative or conducting plate is of silver, on which finely divided platinum has been deposited, this roughness of surface facilitating the escape of the hydrogen; each side of the silver plate is exposed to a plate of amalgamated zinc of the same size, which acts as the positive plate, and is excited by dilute sulphuric acid.

Grove's *gas battery* possesses a theoretical, rather than a practical interest. It is stated, under GALVANISM, that the amount of force set in motion in a voltaic arrangement depends on the difference between the affinity of the two metals for the active principle, or radicle of the acid. The liquid which excites the chemical action is decomposed, its elements are separated, and they either combine with the metallic plate, or accumulate on its surface. By these means the voltaic action is opposed and enfeebled, in consequence of the tendency of the component parts of the fluid to re-unite; for example, when dilute sulphuric acid is used, it is important to get rid of the hydrogen which adheres to the platinum, and produces a counter-current, which may be made evident by connecting a platinum plate, opposed to a zinc plate with a galvanometer wire, when, on attaching to the other end of the galvanometer wire another platinum plate, free from hydrogen bubbles, and plunging both into dilute acid, the needle will be powerfully deflected. In the gas battery a plate covered with oxygen, is opposed to a plate covered with hydrogen. A cell of this battery consists of two tubes; through the upper end of each is soldered a platinum wire attached to a platinum plate extending to the bottom of the tube. The hydrogen tube has twice the capacity of the oxygen, and the tubes are supported in a vessel containing dilute sulphuric acid. At the beginning of the experiment the tubes are filled with the dilute acid, and are charged with gas, by being connected with a voltaic battery. When the tubes are in this way charged, they are separated from the battery, and the mercury cups at the top of the tubes being connected with a galvanometer there is a strong deflection of the needle, and by connecting 8 or 10 cells in such a way that the oxygen of one cell may be connected with the hydrogen of the next cell, sparks between charcoal points and various chemical decompositions may be obtained. The gases gradually diminish in bulk, but the current is maintained so long as they remain uncombined.

For the formation of a voltaic circuit, it is usually stated that two dissimilar metals, and a fluid acting upon one of them, are required. We have seen in the case of the gas battery a variation from this rule, which may be still farther departed from in various ways. For example:—if a single metal be plunged one end into a liquid capable of acting on it, while the other end is dipped into a different liquid communicating freely with the first liquid, but having little or no action on the metal, a current will be established. If, for example, we place in the bend of a U tube a piece of tow, and in one limb pour in a solution of chloride of copper, and in the other limb one of common salt, and connect the two open ends of the tube by means of a strip of copper dipping therein, crystals of copper will be formed upon the end of the strip immersed in the metallic solution, while the end of the strip immersed in the salt and water will be corroded, and chloride of copper be formed. By using various liquids in the two limbs, Becquerel has obtained many of the metals in beautiful crystalline forms. It has also been shown that similar actions are going on within the earth's crust; for by connecting, by means of wires attached to a galvanometer, the surfaces of two contiguous lodes of ore, the existence of feeble but continuous currents was detected.

The battery used at first by Professor Wheatstone for his electrical telegraph was formed nearly on the same principle as that of Mr. Daniell. A small outer vessel contained a solution of sulphate of copper, together with the plate of copper which formed the negative pole; within this, a small porous cell contained diluted sulphuric acid, and at the bottom was an amalgam of zinc and mercury, which constituted the positive pole. Various other forms of battery, and also an electro-magnetic apparatus, have been employed for working the telegraph. [TELEGRAPH.]

A notice of galvanic apparatus would not be complete without referring to Deluc's *dry pile*, which consists of circular disks of paper, one surface of which is coated with leaf gold or silver, and the other surface with zinc foil. Some thousands of these disks are arranged in a glass tube, with all the zinc surfaces in one direction, and the silvered or gilt surfaces in the other direction. If these disks be pressed together, and a wire attached to each end, the leaves of the gold-leaf electroscope may be made to diverge by touching the cap of the instrument with one end of the pile, and connecting the other end with the earth. If the two ends of the pile be made to terminate in metal disks placed about an inch or so from each other, and be well insulated, an insulated slip of gold-leaf suspended midway between them will oscillate backwards and forwards for months, and even years. A dry pile consisting of 20,000 disks gave sparks, and charged a Leyden battery so as to produce shocks. The term dry pile is, however, a misnomer, since the action depends on the moisture contained in paper when exposed to the air: if the paper be artificially dried the pile ceases to act. Zamboni substituted finely-powered peroxide of manganese for the gold or silver leaf, with good effect. The pile terminated in metal plates, which compressed the paper disks by means of ligatures of silk, and the pile was insulated by giving it a coating of sulphur.

In all voltaic actions power is transferred by means of a polar influence propagated through the solid as well as the liquid particles of the circuit. As a consequence of polarisation we get electric tension, the effects of which may be shown by a numerous series of alternations of zinc and copper (Mr. Gassiot's battery consisted of 3520 pairs), each exposing but a very small surface, and excited with distilled water only. Such an arrangement is called a *water battery*, and when well insulated its effects are remarkable. With 1000 couples divergence of the gold leaves of an electroscope was produced, a charge was given to a Leyden battery, which, though weak, could be discharged and renewed any number of times in rapid succession. In Mr. Gassiot's arrangement, when the wires terminated in brass disks, placed very near together, a rapid succession of sparks was kept up, on one occasion, for five weeks; the galvanometer was permanently deflected, and paper moistened with iodide of potassium gave indications of decomposition, although the chemical effects of the water battery are but feeble.

Under Electro-Dynamics will be found some formulæ for estimating the force and resistance of galvanic currents; and we gave a brief statement of Ohm's method of representing the mutual actions of the electro-motive forces, and the resistances of any circuit in the form of a fraction. Now as the power of any combination, simple or compound, is directly proportioned to the electro-motive force, or chemical energy between the active metal, and one of the elements of the liquid on which it acts, and inversely proportioned to the resistances to be overcome, the numerator of the fraction will be represented by E, the electro-motive force, and the denominator by $R+r$, R representing the resistance in the cell or the battery (chiefly due to the affinity between the elements of the liquid for each other), and r all resistances exterior to the cell and the battery, such as that of the connecting wire: then the expression $\frac{E}{R+r}=A$ would represent the effect of any combination where A indicates the amount of force in circulation, whether measured by its heating or by its magnetic effects. If the connecting wire be very thick, so as to offer little or no resistance to the current, r goes out, and the fraction becomes $\frac{E}{R}=A$. Now, suppose that when a pair of zinc and platinum plates, 6 inches in length and 1 inch in breadth, and 1 inch apart, is immersed in dilute acid, $E=1$ and $R=1$ then $\frac{E}{R}=\frac{1}{1}=1$. If a pair of plates, 6 inches broad and 6 inches long, be immersed in the same acid, since the resistance is inversely as the surface of the plates immersed, the fraction becomes $\frac{E}{\frac{R}{6}}$ or $\frac{1}{\frac{1}{6}}=6$, or the power is increased six-fold, as compared with the former. If each of the plates be cut into six similar slips, and these be arranged in pairs, all the platinum plates connected by the same wire and opposed to all the zinc plates similarly connected, the same fraction still represents the result, since the relative size and distance of the plates remain unchanged; but if the plates be made to alternate, the zinc of one pair connected by a wire to the platinum of the next pair, so as to produce a compound circuit, the fraction becomes $\frac{6E}{6R}=\frac{6}{6}=1$, the electro-motive force is increased six-fold, but the resistance is also increased in the same proportion. The force, which in this case circulates through the connecting wire, is not greater than if a single cell, containing a pair of plates 1 inch broad and 6 inches long, had been employed. If, however, the connecting wires were several miles in length, as is the case in the electric telegraph, r becomes important. We will suppose the resistance to be twenty-fold greater than that of the liquid in each cell: then, in the case of the simple circuit, the fraction becomes $\frac{E}{\frac{R}{6}+r}=\frac{1}{\frac{1}{6}+20}=0{\cdot}049$; and in the case of the compound circuit, $\frac{6E}{6R+r}=\frac{6}{6+20}=0{\cdot}23$; so that although in both cases the resistance greatly diminishes the amount of circulating force, the power in the compound circuit is five times as great as that produced by the simple circuit, so that wherever there is a great external resistance, a compound battery is very much to be preferred to the simple circuit. For, let n = the number of plates in a compound circuit, E the electro-motive force, D the distance between the plates, S the area of the plates, l the length of the conducting wire, s the area of a section of the wire, then the action of a compound battery with its extremities connected by a thick metallic wire, is expressed by the fraction $\frac{nE}{\frac{nD}{S}+\frac{l}{s}}=A$. In Professor Miller's 'Elements of Chemistry,' part i., the reader will find some further instructive applications of Ohm's theory. The chemical decompositions produced by the galvanic battery are stated under Electro-Chemistry; and the brilliant light furnished by the voltaic arc is noticed under Electric Light. See also Electrical Egg.

GALVANISM. This department of electricity takes its name from Galvani; but its infant progress was due in a much greater degree to his contemporary Volta, by whom piles were first constructed for increasing the intensity of the electricity produced by a single pair of plates. The production of electricity in this case arises from the action of the acid in the cell between two plates of dissimilar metals, that which is the more oxidable giving out positive electricity, as explained under Electro-Dynamics. The forms in which the piles have been constructed are various, and the number of plates is adapted either to the quantity or intensity of electricity which may be desired. When quantity with a feeble tension is requisite, a single pair of plates, such as zinc and copper, with extensive surfaces, separated by very dilute acid, will answer; but with a system of pairs of plates, where the copper of the first pair *conducts* its electricity to the zinc of the second, and so on, the quantity and intensity are increased with the number of the plates. In some constructions, as Ritter's dry piles, the plates are simply laid on each other, those of each pair being separated by moistened paper; in others the plates lie parallel in a trough of baked wood, by which means the cells are easily filled and emptied. In the *Couronne de Tasses* of Volta the plates are placed circularly or in a bowl shape; while in Hare's *Calorimotor* there is merely one zinc plate and one copper twisted into a great number of coils, which form increases the intensity, as may be seen from the article Electro-Dynamics. All these forms have however been superseded by the constant battery, as noticed under Galvanic Battery.

The electricity thus produced is of the same nature as that given by the common machine; the only difference being that the mode of producing galvanism is continuous, that is, when in any way discharged it is immediately reproduced by the oxidation of the zinc; and hence many galvanic phenomena have been successfully imitated by a series of sparks of ordinary electricity. When the positive and negative wires are made strictly to communicate by metallic conductors, the combination of the opposite electricities causes all phenomena analogous to those produced by the ordinary machine to cease, but gives birth to the electro-dynamic and electro-magnetic phenomena. [Electro-Magnetism.] But when the wires from the opposite poles of the battery are only brought sufficiently near that the current may pass through an interposed substance, or when the circuit is completed by imperfect conductors, the physical changes which the interposed substances undergo constitute the phenomena of galvanism. It may be observed that the relative conductibility of substances for Voltaic is nearly the same as for common electricity, but the alterations produced by the former in the temperature and internal nature of the substances through which the current is admitted interfere in some degree with that order of conductibility.

The deflagration of metals is effected by beating them into thin leaves, which are then interposed between the extremities of the positive and negative wires of the battery, brought within a quarter of an inch of each other: they will then burn with a beautiful light, but which is of different colours in different metals. Thus—zinc gives a white light with a reddish border; copper, a bluish white light, and throws out red sparks; lead, a purple light; gold leaf, a beautiful white light tinged with blue.

But if the interposed substances, instead of being laminæ, be of small irregular forms, or wire-shaped, their temperature rises rapidly as the electric current permeates them. Steel burns, iron wire dissolves in globules, while charcoal produces a light of such dazzling brilliancy as to fatigue the eye, a property which has been happily seized by employing it in the solar microscope [Electric Light]; yet this heat and light are independent of the ambient medium, no oxygen is consumed, and the attenuation of the air rather adds to than diminishes the light. As for the apparent diminution of this intense light when the charcoal is immersed in water, it is attributable to the imperfect conductibility of the latter medium; a thermometer placed in water, in which the wires are immersed, will rise even to the boiling point. Mr. Children has given a list of the order of facility in which substances thus acquire a red heat, and has succeeded in fusing the oxides of molybdenum, tungsten, uranium, &c., but found ruby, sapphire, silex, quartz, &c., more intractable. It is obvious that, in the estimation of such an order, we must take an account of the mass heated, and of the extent of its surface which is liable to cool by contact, radiation, or both; and lastly, of the loss of conductibility due to the increase of temperature of the substance interposed. Ether, alcohol, &c., may be inflamed, and gunpowder exploded, by making the discharge through charcoal points.

Sir Humphry Davy avoided the increase of temperature in the wires through which the current was discharged by taking them of a length sufficient to discharge the number of pairs of plates employed in the pile, and thus found that the length of wire in this case is inversely proportional to the number of double plates. The diminution of conductibility due to increase of temperature he exhibited by a platinum wire made red-hot by the galvanic current; for when he raised one part of it to a white heat by means of a blow-pipe, the heat in the other parts of the wire became immediately reduced. The order of heating in metals, beginning from that most susceptible, which he has given, is as follows:—iron, palladium, platinum, tin, zinc, gold, copper, silver.

Under Electro-Chemistry will be found a statement of the relation subsisting between chemical changes and galvanic electricity. We may however in this place state some of the early results obtained.

The decomposition of water by the battery is effected by bringing the points of the positive and negative wires very near each other under water, inverted glasses being placed over them to collect the gases which are evolved. If the wires be not oxidable, then oxygen gas will be formed at the extremity of the positive wire, and hydrogen at the negative, in the same proportions in which they constitute that liquid; but if oxidable, then the positive wire will be covered with an oxide, while the negative wire still produces hydrogen gas. In general oxygen and chlorine are found at the positive pole, and the other gases at the negative; but we are not to suppose that oxygen only is disengaged by one wire, and hydrogen only by the other; for the particles of water in contact with the ends of either wire are strictly decomposed into their constituent gases, but the oxygen formed at the negative wire is transferred to the positive, and the hydrogen at the positive is transferred to the negative.

The chemical analysts were at first somewhat puzzled at finding foreign products, when producing decomposition by galvanism; soda, which was sometimes found, was due to the decomposition of small portions of the glass in which the experiments were made, and muriatic gas to vegetable substances employed occasionally, as wet cotton-thread, when the liquid was contained in separate vessels having only this mutual communication.

When neutral salts were held in solution and exposed in the same manner to the galvanic action, their alkaline bases were found at the negative wire, and the acid at the positive: thus zeolite was decomposed into soda and lime; glauber salt into solution of soda and sulphuric acid; while the metallic solutions gave their crystals and oxides to the positive pole, and transferred the acids to the negative. Davy made the remarkable discovery that this transfer took place without any combination being effected with the parts of the medium traversed, even when the latter had a great affinity for the elements which passed through it. He arranged three cups, in the first of which was a solution of litmus, in the second a similar solution, and in the third sulphate of soda. The positive wire was immersed in the first cup, the negative in the third; and the intermediate one was connected with the two extreme cups by means of a moistened thread, so as to complete the circuit: the result was, that the solution of litmus in the positive cup became red, indicating the transfer of the acid from the third cup, while the similar solution in the intermediate cup underwent no change, clearly showing that the acid in its transfer did not combine with the solution through which it passed. Similarly, upon reversing the poles, a green was produced in the first cup, while the middle still remained unaffected. But he soon recognised that there was an exception to this, namely, when the transmitted substance and the medium combine so as to form an insoluble compound; for when it has thus acquired a greater specific gravity than the medium, it is necessarily drawn out of the line of transference; and if by mechanical means it should be preserved in it, the transfer will go on as before.

It may be observed generally, with respect to chemical decompositions effected by galvanism, that it is quantity rather than intensity which is requisite, and that the metals, alkalies, and earthy bases are transferred to the negative pole; the acids, oxides, and chlorides to the positive. By the successive labours of Davy and other chemists, different substances which had before been supposed simple, as soda, potash, lime, baryta, strontia, magnesia, zircon, &c., were analysed by this powerful instrument; and though silex, alumina, &c., offered great resistance to its application, and the metallic bases were with difficulty restrained from again combining with oxygen, still in the majority of cases the analysis has been successful. The same method was applied by Brande to fluids containing albumen, when albumen and alkali were found at the negative pole, albumen and acid at the positive; he also found that though it remained fluid with a weak battery, when a stronger one was employed it was separated in a coagulated form. Experiments of the same nature were made by Golding Bird, whose results do not agree with those obtained by Brande. He used for his battery the Voltaic form, a *Couronne de Tasses* of thirty small plates, excited only by a weak solution of salt, and first operated on liquid albumen in a state of non-combination. Putting serum of blood into a glass vessel, and having introduced the wires of the battery, a cloudy deposition took place near the positive wire without adhering to it. The experiment being next made with two vessels connected by moistened cotton, coagulation took place in the positive vessel, while none occurred in the negative; after a time the contents of the former had an acid taste, and of the latter a caustic alkaline flavour: when all in the positive vessel was coagulated by the galvanic action, he found there hydrochloric acid mixed with chlorine, and the alkali in the negative vessel. He has given also an explanation of the causes of the difference in Brande's results.

An interesting class of experiments is due to Mr. Crosse on the employment of electricity, in a state of high tension, to form mineral and other substances. There is a cavern near Broomfield, of which the vault is covered with arragonite and carbonate of lime and fine crystals. The water which drips from this vault holds in solution ten grains of carbonate of lime and a little sulphate of the same to each pint. A glass filled with this water was submitted to the action of a battery consisting of 200 pairs of plates, and at the expiration of ten days the negative pole was found to have formed rhomboidal crystals of carbonate of lime, accompanied by some gas-bubbles, and in less than a month after the wire was covered with regular and irregular crystals, whence it follows that the bi-carbonate was decomposed into carbonate and carbonic acid gas. He also let the water drop on a piece of brick subjected to a current from 100 five-inch plates, the brick being supported by a funnel which conducted the water into a vessel below; after four or five months the brick near the negative pole of the battery was covered with carbonate of lime, while near the positive pole were disposed prismatic crystals of arragonite; and the same experiment being repeated with fluosilicic acid, regular hexahedral pyramids similar in all respects to quartz were obtained; those which were left in a dry place acquired sufficient hardness to scratch glass; the others had not that power, and gradually lost their transparency. In his varied experiments of this nature he succeeded in forming, by means of the galvanic battery, the following minerals:—carbonate of lime; arragonite; quartz; protoxide of copper; arseniate of copper, and its blue and green carbonates; phosphate of copper; carbonate of lead; chalcedony, &c., upon which Becquerel remarks, in his 'Experimental Electricity,' "nearly all these substances we have obtained these dozen years with the *simple* electro-chemical apparatus."

We now pass on to a brief notice of the physiological effects produced by galvanism, from which we must exclude any account of the animalculæ observed by Mr. Crosse in the solutions employed in his experiments.

In the life of GALVANI, in BIOG. DIV. [see also VOLTA] there is an account of the convulsive motions to which denuded frogs are subject when the nerve and muscle form part of the galvanic circuit. In order that an individual may receive a shock from a battery, it is advisable to moisten the hand, because the dry cuticle is a bad conductor of electricity: then, on holding one of the wires of the battery and touching the other, the shock will be received and felt in the wrists, arms, or shoulders, according to the intensity of the current; or a continued sensation, resembling the piercing of a very fine needle, will be perceived by dipping the finger in a dish containing a little water in which the wires of the battery are inserted at the same time with the finger. In both cases, if the nerves are denuded by a cut, the sensation is painful, and the pain will remain some time before it subsides. In some experiments of this kind Humboldt brought on an inflammation by applying the current to a cut. Volta has asserted that the negative wire communicates the greater pain.

A flash of light is perceived by covering the bulb of the eye with tinfoil and forming a metallic communication thence with the mouth, as for instance with a silver spoon; also Berzelius found an acid taste on dipping the tongue into a zinc vessel containing water, which was placed on a silver stand, by touching the silver with his hand so as to complete the circuit. When the negative current is communicated to the taste, it is caustic and alkaline.

When the battery is applied to a nerve of a person recently dead, and the circuit is completed, several violent motions ensue, dependent on the relative position of the nerve and muscle; thus, when the wire communicates with the phrenic nerve, the muscles of respiration are set in motion; when from the ulnar nerve to the spinal marrow is included in the circuit, the fingers are set in quick motion, and so on. Fishes are still more susceptible of this electric action than animals, and strong convulsive motions will be exhibited by a live flounder placed on a zinc dish and having a piece of copper or silver on its back, as soon as the two metals come in contact: similar effects take place with leeches, worms, and amphibious animals.

It was thought by Volta that the involuntary muscles, such as the heart, could not be thus excited, but experiment has decided against him.

When the secretion was suspended by cutting the eighth pair of nerves, Dr. Philip and several French anatomists have restored it by establishing a galvanic current through the divided part of the nerves next the stomach.

Intermittent currents have been employed in the experiments of Masson, Peltier, and Delarive. To effect this M. Masson used a toothed wheel rotating by a cord round it; its axis, supporter, and itself being all metallic: a communication is formed between this wheel and a battery in the form of a helix: the object of the teeth of the wheel is occasionally to suspend the action of the current by making the connecting rod of too great a length; hence, when the wheel is made to revolve, the galvanic current acts and is suspended alternately. By a series of intermitted discharges produced in this manner, M. Masson had the cruel pleasure of killing a cat.

It has been ascertained by Matteucci and others, that portions of muscle and nerve present different electrical states with reference to other portions of the same muscle or nerve. For example, the external portion of a muscle may bear the same relation to the internal, as platinum does to zinc in the voltaic circuit. In fact, a voltaic pile may be formed by slices of muscle arranged so that the external part of one slice may touch the internal part of the next, and so on.

P. Santi Linari drew the electric spark from the gymnotus in the following manner:—he took a glass tube of the shape of a capital U, which he partly filled with mercury; at each end was fixed an iron wire through a wooden button, and which reached very near the mercury. The apparatus being fixed with mastic on varnished wood, the ends of the wires were made to touch short platina wires terminated by laminæ of the same metal, intended to make a good communication with the different parts of the electrical fish. When the circuit was formed, a spark visible even in the daylight appeared at the place where the conductors were interrupted. This experiment he repeated in different forms. ('Biblioth. Univ. de Genève.')

M. Delarive has noticed a remarkable difference of effects in the action of Voltaic and of magneto-electric currents. When the wires of the latter were used for decompositions, but in the form of thin leaves or laminæ, there was but little disengagement of gas, and the more the lamina was plunged, the less was the gas evolved, which was not the case in the common form of the wire: this does not occur in Voltaic electricity; the same experimentalist has sought the quantity of electricity necessary to decompose a given quantity of water, and his result is that the product of the time multiplied by the intensity of the current is constant.

Let us now recapitulate the general phenomena of voltaic or electro-chemical action.

If two flat pieces or plates, one of zinc, the other of copper or platinum, be immersed, without touching each other, in diluted sulphuric acid, chemical action, as it is termed, will take place between the zinc and fluid; the water of the latter undergoing decomposition, its oxygen unites with the metal to form a protoxide, while the equivalent of hydrogen is set free, but adheres to the surface of the plate in small bubbles, which gradually coalescing into larger, detach themselves and rise to the surface from their specific levity; the protoxide combines with an equivalent of acid, forming a soluble salt, which, being consequently removed, allows of renewed and continuous action on the metal. In time however the fluid becomes saturated with the sulphate of zinc, which is then thrown down undissolved, and is also deposited on the surface of the plate, acting mechanically to prevent that intimate contact between the pure metal and the water which is essential to chemical action; this obstruction is also in some measure occasioned from the beginning by the adhesion of the bubbles of hydrogen, and consequently that action is gradually retarded and finally ceases. During this time the copper or platinum plate is perfectly inactive, neither of these metals being affected by sulphuric acid, or more properly, owing to the affinity, as it may at present be still called, between those metals and oxygen, being weaker than that which exists between the hydrogen and that element.

Under these circumstances, if a perfect communication be made between the two metals, by causing a wire soldered to the one, to touch that connected with the other, a remarkable change takes place in the phenomenon, the chemical action between the zinc and the fluid becomes more energetic, but the hydrogen, instead of being liberated at the surface of that metal, appears solely at that of the other, although not the slightest effect is produced on the copper or platinum itself; while the connecting wires will be found to exhibit, by their increased temperature and their magnetic state, the usual indications of what is termed an electrical *current* passing along them, and, as is well known, an electric spark is visible at the instant of separating the wires, provided the plates be sufficiently large.

It is now generally admitted that all chemical is connected with electrical action, and that they bear a direct relation to each other, that is, a certain constant quantity of electricity is evolved by the decomposition of each equivalent of any compound, though that quantity varies for different bodies; but it is not clearly known whether the electricity is the cause or the effect of the chemical action, they being perfectly contemporaneous and co-existent to all our means of observation. It follows therefore that the quantity of electricity varies with the extent of surfaces between which the action takes place, as well as with the nature of those surfaces; but with the same two metals and fluid this quantity depends solely on the extent of surface, that is, on the size of the zinc plate.

It has been proved by Professor Daniell that under these circumstances our power of collecting or retaining the electricity evolved from any given surface of metal, depends on the extent of that of the other, or conducting metal, for in the arrangements under consideration the copper or platinum plate simply acts in this capacity, and that this second plate cannot be too large in proportion to the former, to prevent the loss of any of the evolved electricity, which, if it do not meet with a good conductor in its immediate proximity, passes off to some other.[*] The form of our arrangements puts a limit to this inequality in the extent of surfaces of the generating and conducting metals, but a more important principle still further contracts this limit, which must be briefly adverted to.

All electrical action is most easily and consistently explained as the effects of induction [Electricity, Common; Polarity], or of an action exerted by matter, itself in a polar state, producing polarity in surrounding matter; what is commonly called an electrical current is, on this hypothesis, the momentaneous destruction and reproduction of polar forces, acting along a chain of particles sufficiently approximated to admit of the intensity of the forces in that line exceeding that produced on contiguous particles in other and lateral directions. In the voltaic circuit the particles of the fluid form a part of the chain through which the induction, originated by the zinc on the fluid, is propagated, the chemical decomposition is connected with or occasioned by this polarity, the hydrogen of one particle of water quitting its equivalent of oxygen to combine with that of the contiguous particle, and so on throughout until the hydrogen of the particles in contact with the conducting plate, having no oxygen wherewith to combine, is liberated at that surface in its gaseous state; the metallic part of the circuit undergoes no chemical change except at the surface in contact with the fluid, where the polar forces produce oxidation of the metal, and consequent decomposition of that fluid.

If this chain of polarised particles be broken, and the interposed matter be a nonconductor, the current is at once arrested, and the chemical action between the zinc and the fluid nearly ceases; but even a diminution in the conducting power of any part of the circuit occasions a diminution or retardation of that action. The fluid of the arrangement is an imperfect conductor, compared with the metallic part, and if the distance between the metals be increased, the increase of the intervening portion of imperfect conducting matter may occasion a cessation of the action, and always diminishes it in an inverse ratio to that distance. Hence the necessity in all forms of *voltaic batteries* for diminishing as much as possible the quantity of fluid between the metallic elements: consequently the magnitude of the negative or conducting plate cannot be indefinitely increased, if by so doing it becomes necessary, owing to the peculiar form of the arrangement, to increase the distance between the two plates.

Although we are warranted in inferring by analogy that there may be other chemical sources of electro-polar induction than oxidation of a metal, yet at present we are not acquainted with any other that can at all be compared with it in energy; and, of all combination by which this oxidation may be produced, the most efficient is that of a metal and a solution of a metallic salt, the acid of which has a greater affinity for the former metal than it has for that with which it is combined. If therefore a solution of sulphate of copper be used, instead of the simple diluted sulphuric acid of the arrangement, it becomes far more powerful; but this substitution necessitates a precaution to prevent the deposition on the surface of the zinc plate of the metallic copper liberated by the decomposition, which deposition would otherwise almost instantly take place, and thus, by causing both surfaces to consist of the same metal, polar currents would be produced in opposite directions, which would neutralise each other's action.

The precaution alluded to consists in interposing between the decomposing plate and the metallic solution a substance which, while it admits of the passage of the current, and even that of the pure fluid under the influence of that current [Endosmose], mechanically intercepts the solid copper; the arrangement of the "constant battery," as it is technically termed, for which we are indebted to Professor Daniell, consists of a small rod of amalgamated zinc, that is, of zinc the surface of which is coated over with mercury, placed in a membranous bag, or in a porous earthenware cylinder, filled with dilute sulphuric acid, this cylinder or bag being again placed in a copper one filled with a saturated solution of sulphate of copper; this external copper vessel constitutes the conducting plate, and has the connecting wire soldered to it, while the other wire is attached in any convenient mode to the zinc rod. It must be observed that the membrane or porous cylinder must be perfectly continuous: the least fissure would admit of the passage of the copper to the zinc, and destroy the effect.

As long as the two wires do not touch, this battery is nearly quiescent, except the slight local action which takes place between the zinc and its surrounding fluid;[*] but when the circuit is completed by making the ends of the wires touch, the action becomes energetic, the solution of the sulphate of copper is decomposed, the reduced metal being deposited on the surface of the copper vessel; it is consequently necessary to maintain the supply by adding from time to time solid sulphate to the solution, so as to keep it always saturated; for it must be distinctly understood as a fundamental principle, that, without continuous chemical decomposition and recomposition, no current or circle of electro-polar forces can be maintained.

Let the ends of the two wires, not in contact, be plunged into a liquid compound, such for example as sulphate of copper in solution, which, being an imperfect conductor, is capable of decomposition; decomposition of it will accordingly take place, and in the same direction as that in which it occurs in the fluid of the battery; that is, the copper of the solution will be determined to or precipitated on the wire connected with the zinc plate, while the other wire will be dissolved, uniting with the free acid to produce a sulphate. It may be asked how it happens that the copper wire is dissolved while the plate of that metal in the battery is not acted on, and what becomes of the hydrogen which was liberated in a free state, when dilute acid alone was employed. This apparent contradiction is explained by an attentive consideration of the constant direction of the current, and the consequences of its passing through the two portions of fluids in opposite directions as regards them. At the zinc plate the action is the same as before, but by virtue of the current-affinity the copper is determined to the conducting plate instead of the hydrogen, which plate therefore remains unacted on; in the other portion of fluid the wire connected with the copper plate becomes the analogue of the zinc, and the water undergoing decomposition at its surface, the oxygen unites with the copper of the wire to form a protoxide, which combines with the free sulphuric acid, while the copper of the sulphate is again determined in the direction of the current, in preference to the hydrogen, to the surface of the other wire.

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[*] If a large electrical machine were provided with a small conductor, this might become charged by half a turn of the handle, and must discharge itself laterally to the nearest conductors before it could receive a fresh charge.

[*] The object of amalgamating the zinc rod is to prevent this local action, which arises from the inevitable want of perfect homogeneity in the metal; any the slightest difference in two portions of which will cause them to act as positive and negative elements of a small circuit, and a great number of these causes that action on the zinc which takes place before the great or principal circuit is completed; the perfect conducting power of the mercury appears to destroy or neutralise these partial currents, as that of the battery itself would be destroyed if the two plates were connected within the fluid by a perfect conductor, instead of having an imperfect one interposed between them.

This example explains why, during electrolytic decomposition, the elements of a compound are determined in definite directions to one or other pole of the battery: and hence the classification of those elements into *electro-positive* or *electro-negative*, or into *Cations* and *Anions*, according to the nomenclature proposed by Professor Faraday. [ELECTRO-CHEMISTRY.]

When the elements of a voltaic arrangement are single, or when it consists of a pair of plates only, the current, however abundant as regards what may be called *quantity*, is deficient in *tension*, or in that quality which pre-eminently characterises the electricity of friction: an increase of tension, as well as of quantity, is obtained by combining two or more single batteries, the copper element of the one being connected with the zinc of the next by a perfect conductor, and so on in continued succession. In constructing such compound arrangements, or batteries, it must not be inferred that the quantity and tension depend simply on the extent of the surface of the plates taken collectively, and on their number; it has been proved by Daniell, Faraday, and others, that the maximum effect is obtained from a given amount of surface and a given number of combinations, when all the plates are exactly equal; and that if one pair of the series is much larger or smaller than the rest, there will be no additional power gained in the first case, and a considerable loss in the second, nearly equal to what would have been produced if all the plates had been reduced to the size of the smaller.

The term *tension*, as applied to the property imparted to the voltaic current by compound combinations, is, perhaps an injudicious one; since it suggests the idea of some resemblance to the quality of frictional electricity alluded to, which, as will be presently stated, is not precisely the case, but that a very decided modification of the active qualities of the current is produced by these combinations is shown by the fact that the decomposition of a fluid electrolyte into its constituent elements cannot be effected by a single pair of plates, however extensive their surface; while this decomposition becomes energetic by means of a combination of four or five small batteries, the total surface of the plates of which is far less than that of the single one.

The most energetic form of small constant battery is that suggested by Mr. Grove, the elements of which are amalgamated zinc and sheet platinum, the latter being immersed in concentrated nitrous acid, while the zinc element is plunged in dilute hydrochloric acid isolated by porous chambers. The platinum is not acted on, and consequently the plates are lasting, although costly at first. The zinc is of course rapidly destroyed, as it must be in all energetic arrangements, for reasons before given.

In constructing the *science* of electricity, the mind has, as in other sciences, proceeded from first observed facts to simple generalisations, or *theory*, which have again served as guides to new observations and more comprehensive generalisations. Small as the progress yet made has been, and slight as our knowledge is, when compared with what remains to be acquired, we are warranted in concluding, from the steady adherence to the principles of inductive philosophy which has long characterised our investigations, that the present *theory* of this science will be an admitted one, divested as it is, and ought to be, of any attempt to explain ultimate causes, and limited to comprising in general expressions the combined results of past observations, to be tested by its accordance with new ones as they occur. What electricity is, or more correctly speaking, what is the nature of that unknown agent which is the cause of electrical action in the most comprehensive sense of this term, we are utterly, and probably ever shall be, ignorant; but this agent appears to be as inseparable from matter as gravitation, and polarity appears to be the consequence of its presence in an active state. It can be elicited, or brought into this active state, by different causes, and what is remarkable, it presents some striking modifications in its sensible properties, according to the cause which has immediately called it into action; it was these modifications which prevented its recognition when first obtained by chemical action, or by other than mechanical means, and caused it to be denominated *galvanism* or *voltaism*, and yet longer concealed the constant connection, if not identity, between it and magnetism.

That the ultimate cause of these modified modes of action is identical, we are warranted in inferring from the identity of the phenomena which they all produce, and from the interchangeable relation of cause and effect that exists between these various sources of electrical excitation; thus we infer that the unknown agent alluded to is the cause of electricity, voltaism, magnetism, and heat, for each of these may be produced, and each in its turn is capable of producing the others. Friction is the source of an electrical action which produces light, heat, chemical action, and magnetism, but chemical action is the most abundant source of this agent, and all these phenomena are produced more freely by it than by the others; nevertheless the presence, even in the least appreciable degree, of any one of them, warrants us in admitting the identity of the cause. Magnetism is always co-existent with the agent alluded to, but under certain conditions of direction of the electrical and magnetic polarities. Whether that agent be elicited by mechanical or chemical action, or by changes of temperature in different metals [THERMO-ELECTRICITY], and conversely by employing magnetism as the immediate exciting cause, chemical action, heat, light, and magnetism itself may be produced. [MAGNETO-ELECTRICITY.]

The most remarkable and obvious of the modifications which have been above alluded to are those which have given rise to the terms *electricity of tension*, and *current-electricity*, the former characterising frictional or mechanical, the latter chemico-, thermo-, and magneto-electricity; but it is now acknowledged that these terms are only expressive of the highest and lowest degrees of a common property. The spontaneous disruptive discharge which takes place through very imperfect conducting media, such as dry gases, from a body supercharged with frictional electricity, has never yet been produced by the most redundant quantity of chemico-electricity. Contact must be made by some good conductor before the *current* can pass; although the current will continue for a short time after that contact is again broken, but only through a small intervening space, never exceeding an inch or two, between the anode and the cathode, the continuity of the current under these circumstances being indicated by the intense arc of flame between the points terminating the connecting wires of an extensive compound battery; and in the case of thermo- or magneto-electricity it is only at the instant of breaking the contact that the spark appears, indicating the momentary transit through an unappreciable distance of the current, which is instantly arrested when that distance becomes sensible: yet that the electricity from these three sources possesses some tension has been proved by the charge imparted to a Leyden jar from a voltaic battery, and by other indications of the presence of that quality in feeble degrees, both in thermo- and magneto-electrical currents, as for example by the decomposition of solution of iodide of potassium when the anode and cathode are very near to each other.

That power to which the name of *induction* is given, and which is the consequence of the more comprehensive agency termed *polarity*, is another and universal characteristic of electrical action. [ELECTRICITY, COMMON.] The inductive power of frictional electricity and of magnetism were the earliest observed facts in the science, but it is only within a few years that the same power has been shown to accompany the other sources of excitation, owing to the low degree in which they possess it when compared with the former: but now by means of the multiplier or coil, the inductive power of the current from a single pair of plates may be made manifest, especially by the physiological action called the *electrical shock*, which thus modified cannot be distinguished from that obtained from a charged Leyden jar.

We must also glance at another source of electricity namely *vitality*. Are we yet warranted in assigning this as another effect of the same agent? This question cannot be answered; all we as yet know is, that animal electricity as exerted at volition by the Gymnotus, Torpedo, and perhaps other animals, is capable of producing induction, and therefore attraction, heat, light, chemical action, and magnetism, and the physiological action on living bodies, identically in the same manner as the electricity from inorganic sources. [ELECTRICITY OF ORGANIC BEINGS, in NAT. HIST. DIV.]

In comparing the discharge of the galvanic battery with that of the common electrical machine, we may remark that the current is a continuous succession of discharges of electricity generated and maintained by the contact and chemical action of the materials of the battery, and like the discharge of the electrical machine it may be classed under three heads, namely, the discharge by *conduction*, as when the circuit is completed by a good solid conductor; by *disruption*, when a luminous appearance is seen through a short interval of non-conducting matter; and thirdly by *convection*, which takes place in liquids, and is accompanied by chemical action, and the transfer of particles of the conductor.

When electricity, however produced, is in motion, all the particles of the conductor are concerned, in conveying the force, and not the surface merely, as in static electricity. [ELECTRICITY.] In such a case induction takes place between one transverse section of the conductor and other sections just before and behind it, while a small but sensible portion of the induction is directed to surrounding objects. If the thickness of the conductor be reduced the particles have to transmit a larger portion of the force, and the result is a considerable elevation in temperature, sufficient to ignite and even fuse the wire, a circumstance taken advantage of in firing the charge of gunpowder used in blasting. Metals degenerate in conducting power by elevation of temperature, as may be well shown by raising a platinum wire to a dull red heat, by sending a voltaic current through it, and heating a portion of the wire by means of the flame of a spirit-lamp; the temperature of the other part of the wire will decline, and the wire cease to be visible, in consequence of the increased resistance offered to the current by that part of the wire which is in the flame. A contrary effect is produced by cooling a portion of the wire in water, the reduced temperature at one point allowing more electricity to pass, as is manifest by the light given off by the wire, which may even fuse and disappear in globules.

We have stated under GALVANOMETER the method adopted for ascertaining the conducting power of metals for electricity. The following table shows the conducting power of wires of the same length and diameter, by which it will be seen that these powers vary with the temperature, the effect of a moderate rise of temperature in reducing the conducting power being considerable :—

Metals.	At 32° Fahr.	Silver at 32° Fahr., being equal to 100°.	At 212° Fahr.
Silver . . .	100·000	71·316	100·000
Copper . . .	91·517	64·919	91·030
Gold . . .	64·960	48·489	67·992
Cadmium . .	24·579	17·506	24·547
Zinc . . .	24·068	17·596	24·673
Tin . . .	14·014	8·657	12·139
Iron . . .	12·350	8·387	11·760
Lead . . .	8·277	5·761	8·078
Platinum . .	7·933	6·688	9·378
Mercury . . .	1·738	1·575	2·208

When equal amounts of electricity traverse similar wires of different metal in equal times the rise of temperature in the wire is inversely proportioned to its conducting power, so that the better the conductor, the smaller is the quantity of heat emitted by it. A compound wire formed of equal alternate portions of silver and platinum will transmit a current so as to heat the platinum links to visible redness, while the silver from its superior conducting power will not become luminous.

If a Leyden jar or battery be repeatedly discharged through a platinum wire too thick to be fused by it, the wire will become shortened as if it had been acted on by a force transverse to its length. A similar effect takes place with voltaic electricity. If a platinum wire be arranged in a porcelain trough, so that when fused it shall retain its position as a wire, and a strong current be sent through it, it will snap asunder when near the point of fusion, thus showing a contraction in length, while if a similar experiment be performed with lead wire, it will gather up in nodules which encroach on each other as if from longitudinal compression. It has also been noticed that telegraph wires which have been long in use become brittle, and it has been ascertained that while a wire is transmitting the electric current there is a temporary diminution in the co-efficient of elasticity independent of the heating effect of the current.

Liquids are greatly inferior to solids in conducting power, so much so that it is difficult to compare them. According to M. Pouillet, a platinum wire conducts 2,500,000 times better than a saturated solution of sulphate of copper. In many liquids the conducting power rapidly increases with the temperature, a result contrary to that obtained with solids. Gases are almost perfect insulators of the voltaic current.

With respect to the disruptive discharge, we have an instance of it in the fusion and dispersion in vapour of the conducting wire, when not of sufficient capacity to convey the current. By rarefying the air between the ends of the terminal wires, the space through which the discharge will take place may be increased. In the large battery of 2000 pairs at the Royal Institution, Davy obtained an arc of flame between charcoal points, 4 inches in length. In such cases there is a transfer of solid particles from one pole to the other which increases the effect. A cavity is produced in the piece of charcoal attached to the last platinum or copper plate of the battery, and a mammelated deposit is formed on the charcoal connected with the last zinc plate. Even the densest metals, such as platinum and iridium, are transferred from one pole to the other.

The discharge by convection introduces us to the beautiful and important branch of science, Electro-Chemistry, to which we refer.

GALVANISM, in its action on the human system, resembles electricity, yet it is distinguished by certain peculiarities. In its application it can be rendered more continuous and uniform, and may, like electricity, be administered either in shocks, or in a regular flow of galvanic influence through the body. It possesses more power over the chemical actions of the body than electricity, and promotes more completely those processes of decomposition and recomposition which take place in the living frame, as well as the functions of organic life, than common electricity. But the chief distinction consists in the difference of action of the two poles. Each pole excites peculiar phenomena in the organs to which it is applied. This difference is less perceptible when mere shocks are administered, than when a continuous stream of galvanic influence is transmitted from one point to another of the body. The positive pole more particularly influences the muscular and vascular system, while the negative pole more especially affects the nervous system. At the positive pole there is felt the shock, strong movements, a feeling of concentration and contraction, increased warmth and mobility of the part, with gradual diminution of the secretion and sensibility. At the negative pole the pain and sensibility are stronger and more acute, the organ expands, is more irritable, while the muscular action and mobility are lessened. The difference of their action on the secreting powers is best seen by applying the respective poles to a surface which has been recently deprived of its cuticle, such as where a blister has been. The positive pole changes the serous secretion into that of lymph, which at last becomes thready; the part dries and is inflamed. The negative pole causes an abundant secretion of a dark-coloured, highly acrid fluid, which excoriates the skin over which it flows; the part also experiences an enduring irritation. Atonic swellings are rendered harder, should they not become inflamed by the positive pole, while frequently by the negative pole they are dispersed and resolved. Notwithstanding the possession of such powerful properties, galvanism has not produced so valuable results in medicine as might have been anticipated. This comparative failure is no doubt to be attributed to errors in the mode of applying it. As the diseases in which it has been recommended are those already enumerated under electricity [Electricity, Medical uses of], it is not necessary to repeat them here. It may be proper however, to remark, that it was urgently recommended during the prevalence of the Asiatic cholera, but the results were not satisfactory. Like many other powerful agents, it was not used till a very late stage in the complaint, when recovery was almost impossible. It is also to be doubted whether galvanism be at all applicable to cholera, since it appears that the continued application of it causes death, by inducing inflammation of the lungs, in cases of animals where the eighth pair of nerves have been divided, more speedily than where the same nerves have been divided in animals to which the galvanic power was not applied as a substitute for the nervous. Inflammation is the invariable consequence of the application of the positive pole; while the negative pole would cause a flow of acrid secretion which could not benefit the patient. The identity of electricity, whether common or galvanic, with the nervous power, is much to be questioned, but on this subject Matteucci has entered at some length in his numerous papers. (See Delarive's 'Electricity;' and the controversy between Dr. W. Philip, Dr. Williams, and others, in 'Medical Gazette,' vol. xvii.)

The part to which the poles are applied requires to be moistened, where a slight effect is wished, with plain water; but when more powerful effects are wished, with salt and water.

GALVANO'METER, or MULTIPLIER, is an instrument constructed for the purpose of detecting the presence of feeble electro-chemical currents. The nerves and muscles of newly killed frogs were at first used; but the discovery of electro-magnetism has furnished a more delicate and measurable criterion: the instrument founded on this principle has been successively improved in the hands of Schweigger, Cumming, Nobili, and Melloni, to a most remarkable degree of delicacy.

The principle of the construction depends on the property possessed by electrical currents of acting on magnetised needles; for if the conducting wire be placed on the magnetic meridian above or below the needle, the latter will suffer a deviation to the right or left according to the direction of the current. [Electro-Magnetism.]

The action of terrestrial magnetism tending to restore the needle, after its derangement by the current, to its original position, is almost entirely corrected by employing two similar needles supported parallel to each other by a light piece of straw or other substance, and placed with the poles of one in an inverse position to those of the other. A pair of needles thus arranged forms what is termed an *astatic* combination, (from *αστατος*, indifferent.) The needles are delicately suspended by means of a thread of untwisted silk or a filament of glass in such a way that the lower needle shall be within a coil of copper wire covered with silk or cotton, and making several hundred convolutions. In such an arrangement the needle which is outside the coil will be acted on by the upper wires only, the lower ones not being sufficiently near to produce any effect: and this action coincides with their action on the lower needle with its reversed poles, so that the effect of a feeble current is materially increased. The apparatus is usually inclosed within a glass case, and there is an adjusting screw at the point of suspension for raising or lowering the silk, so that when the instrument is not in use the needles can be let down so as not to drag upon the suspending fibre. Over the coil, but below the upper needle, is a sheet of copper, graduated so as to show the angular deviation of the needles. There are also binding screws for connecting the ends of the coil with the wires which transmit the current. There are also levelling screws and a lever for placing the coil parallel with the needles so as to make them coincide with the zero of the graduated circle. Thus the galvanometer not only indicates the presence of voltaic action, but estimates its amount. When the needle does not deviate more than 15° or 20° the amount of force may be considered as accurately represented, but for larger angles such is not the case, since the more the needle deviates from parallelism to the wire the more obliquely and consequently less powerfully does the force act. For example, more force is required to move the needle from 20° to 25°, than from 10° to 15°; but as the deviation in each case is definite for the same instrument the measurements may be so far relied on.

M. Becquerel's *Differential Galvanometer* consists of two insulated copper wires of equal length and diameter surrounding the needles, forming two independent circuits, and having four terminations instead of two. This instrument was used for estimating the conducting power of the different metals for electricity which varies nearly in the same order as their power of conducting heat. Now it is evident that if two equal currents were sent in opposite directions through the two coils of the above instrument they would neutralise each other in their action on the needle which would remain undeflected; but if one current were stronger than the other there would be a corresponding deviation of the needle. In using the instrument a small voltaic battery was connected with it, with two wires from each pole so as to divide the current into two equal portions, one of which was transmitted through one of the coils, and the other through the second coil in an opposite direction. When wires of different metals were introduced into the two circuits, a wire of inferior conducting power would show a diminution in the current and a deflexion of the needle, but equilibrium was restored by varying the length of one of the wires, and by comparing the lengths of the wires thus introduced their relative conducting powers were arrived at. With this instrument, assisted by Wheatstone's *rheostat*, the conducting powers of a number of wires of different metals were accurately ascertained.

There are various instruments with various names used for measuring, directing, or reversing the voltaic current. Some writers do not content themselves with so simple a word as *Galvanometer*; but use other and more recondite terms, and often so copiously that scientific nomenclature, like diplomatic speech, seems to be intended *pour cacher la pensée.* For example, an apparatus used for generating a voltaic current is no longer called a *battery*, but a *Rheo-motor*, from ῥέω to flow, and *moveo* to move, while the wire which conveys the current is called the *rheophore*, from ῥέω and φορεω to bear. The whole circuit is also called the *rheophoric* circuit, while the instrument which detects the existence of an electrical current is called, instead of a *galvanoscope* a *rheoscope*, from ρεω and σκοπεω to see. If used for measuring the current it is not called a *galvanometer* but a *rheometer*. The little instrument used for reversing the currents is called a *rheotrope* (τρεπω to turn); that for periodically interrupting the current is a *rheotome* (τεμνω to cut off); while that for maintaining the current at any degree of force is a *rheostat* (σταω to stand or remain). The reader will find these instruments described in Harris's 'Rudimentary Treatise on Galvanism,' 1856.

GAMBIR. [TANNIC ACID.]

GAMBIT. [CHESS.]

GAME-LAWS were the remnant of the ancient forest-laws, under which the killing one of the king's deer was equally penal with murdering one of his subjects; or, as Sir W. Blackstone somewhat quaintly expresses it, "from this root has sprung a bastard slip, known by the name of the game-law, now arrived to and wantoning in its highest vigour, both founded upon the same unreasonable notion of permanent property in wild creatures, and both productive of the same tyranny to the commons; but with this difference,—that the forest-laws established only one mighty hunter throughout the land, the game-laws have raised a little Nimrod in every manor." Some portion of the history of the game-laws in England will be found under FOREST LAWS, and WARREN, FREE.

These laws decided what birds and beasts should be deemed game, prohibited all persons not duly qualified by birth or estate from killing any such prohibited creatures, or even from having them in their possession as articles of food, and inflicted severe punishments and penalties upon the offenders against their provisions.

By the last general statute on the subject (2 Wm. IV. c. 32), game is declared to include hares, pheasants, partridges, grouse, heath or moor game, black game, and bustards. Snipe, quail, landrail, woodcocks, and conies are not game.

The statute 13 Richard II. c. 13, the title of which was, "None shall hunt but they who have a sufficient living," was the first introduction of a qualification to kill game. This statute prohibited laymen who had not lands or tenements of 40*s.* a year, and priests who had not 10*l.* a year, from taking or destroying deer, hares, or conies, upon pain of one year's imprisonment. By 3 Jac. I. c. 13, the qualification to kill game was increased to 40*l.* a year in land and 200*l.* in personal property. By 22 & 23 Car. II. c. 25, the qualification was limited to persons who had an estate of inheritance of 100*l.* per annum or an estate for term of life or 99 years, or upwards, of 150*l.* annual value. On this Blackstone remarks, there was "fifty times the property required to enable a man to kill a partridge as to vote for a knight of the shire." Qualifications were also of a personal nature, as being the son and heir-apparent of an esquire. Persons who had not these qualifications were not allowed to have or keep game-dogs. After repeated discussions in and out of Parliament, by the statute 1 & 2 Wm. IV. c. 32, the necessity of any qualification for the killing of game was abolished, and the right was made to depend simply on the payment of an annual tax, called a game certificate.

Certificates were first required to be taken out by persons qualified to kill game by the act 25 Geo. III. c. 50. The certificate itself, which costs 3*l.* 13*s.* 6*d.*, must be taken out annually, and it expires in July. A sportsman who refuses to show his certificate when demanded by collectors of taxes, gamekeepers, landlords, occupiers, and lessees, is liable to a penalty of 20*l.* Uncertified persons who kill or take any game, or who use any dog, gun, &c., for the purpose of searching for, or killing, or taking game, are liable, on conviction before two justices, to a penalty not exceeding 5*l.* for each offence, with additional penalties under the Certificate Act of 23*l.* 13*s.* 6*d.* Certificates are required not only to enable persons to kill game, but also woodcocks, snipes, quails, landrails, or conies (except by the proprietors of warrens or of any inclosed ground whatever, or by the tenant of any land, either by himself or any person by his direction or command).

By the statute 11 & 12 Vict. c. 29 (1848), reciting that "it has been found that much damage has been and is continually done by hares to the produce of inclosed lands, and that great losses have thereby accrued and do accrue to the occupiers of such lands," power is given to persons in the actual occupation of inclosed lands, or the owners, who have the right of killing game thereon, to take, kill, and destroy hares themselves, or by some person authorised by them in writing, without a game certificate. The same statute authorises persons to course or hunt hares without a certificate.

The right which a certificate gives to kill game is subject to a number of restrictions. A certificated person is liable to a penalty of 5*l.*, with costs, for taking or killing game on Sunday or Christmas-day, and to a penalty not exceeding 20*s.* for each head of game taken or killed at the season when the pursuit of each kind of game is prohibited. The certificate, of course, does not confer any right to enter on land to kill game except where there is a right by ownership or permission so to enter. The certificated person is still subject to the general law of trespass for going upon another person's land.

The right to the game is vested, by 1 & 2 Wm. IV. c. 32, in the tenant in all cases where it is not reserved to the landlord in his agreement with the tenant; but the game is generally coveted by the landlord, and few tenants are in a situation to oppose their landlord. The consequence is that the game is reserved by the landlord when he lets his land; and when this is the case, the occupier can neither kill game nor give permission to another person to do so, and he is liable, under 1 & 2 Wm. IV. c. 32, to a penalty of 20*s.*, with costs, for every head of game killed by him or other persons authorised by him. When the landlord reserves the game, he may not only himself kill it on the tenant's land, but he may authorise any certificated person to enter on the land and kill it. The person who has the right of killing the game, or the occupier of the land, or gamekeepers, or any person authorised by either of them, may require a person found trespassing in pursuit of game to quit the land, and to give his name and place of abode; and in case of refusal, the trespasser may be taken instantly before a magistrate, who may fine him 5*l.*; but if not brought before a magistrate within twelve hours, proceedings must be taken by summons or warrant. If five or more persons together trespass in pursuit of game, and any one of them be armed with a gun, and if threats or violence are used to prevent any authorised person from approaching them for the purpose of requiring them to quit the land, or to tell their names and abodes, every person so offending is liable to a penalty not exceeding 5*l.*, in addition to any other penalty, with costs.

The law is very severe against persons not authorised, who take or destroy game by night. By 1 & 2 Will. IV. c. 32, "day-time" is to be deemed from one hour before sun-rise to one hour after sun-set. The 9 Geo. IV. c. 69, enacts, that if any person by night shall take or kill game or rabbits on any land, or shall enter therein with gun, net, engine, or other instrument, for the purpose, he shall, on conviction before two justices, be committed to hard labour in the house of correction for a term not exceeding three months, and, at the expiration of that period, find securities for twelve months, himself in 10*l.* and two others in 5*l.* each, or one security in 10*l.* In case of not finding sureties (and it is not a likely case that night-poachers should be able to find them), the offender may be further imprisoned six months. For a second offence the term of imprisonment is extended to six months, the sureties are doubled, and required for a period of two years. If the offender cannot find sureties, he may be further imprisoned for twelve months. The third offence was punishable with transportation for seven years, now penal servitude, or imprisonment with hard labour in the house of correction for a term not exceeding two years. Offenders under this act may be apprehended on the spot by owners and occupiers of land, their servants and assistants; and if they assault or offer violence with gun, club, stick, or otherwise, they are liable to penal servitude for seven years, or to be imprisoned with hard labour for two years. The punishment for night-poaching is still more severe when three or more persons enter any land for the purpose of taking or destroying game or rabbits, armed with a gun, bludgeon, or other offensive weapon (and sticks and stones may be offensive weapons) and they are subject to penal servitude for a period not exceeding fourteen years, or to imprisonment with hard labour for not exceeding three years. In 1844 an act was passed (7 & 8 Vict. c. 29) which extended the provisions of 9 Geo. IV. c. 69, against night-poaching to persons who take or kill game or rabbits upon public roads or highways, and other roads and paths leading to enclosed gates, and also at the gates, outlets, and openings between such lands and roads or paths.

By s. 36 of 1 & 2 Wm. IV. c. 32, it is enacted, that if any unauthorised person be found by day or night on any land in search of game, and have in his possession any game which "appears to have been recently killed," any authorised persons, as gamekeepers, occupiers, or others who have the right of killing the game, may demand such game and seize it if not immediately delivered.

A penalty not exceeding 10*l.* is incurred for laying poison with intent to destroy game (1 & 2 Wm. IV. c. 32).

If any person who is not authorised to kill game himself, or who has not permission from a person who has such right, shall take out of the nest or destroy the eggs of any bird of game, or of any swan, wild duck, teal, or widgeon, or shall knowingly have in his possession any such eggs so taken, he shall be liable on conviction to a penalty not exceeding 5*s.*, with costs, for each egg (1 & 2 Wm. IV. c. 32, § 24).

By the act 7 & 8 Geo. IV. c. 29, it is felony to course, hunt, snare, carry away, kill or wound, or attempt to kill or wound, any deer kept in any inclosed land, whether forest, chace, or purlieu, or other place wherein deer is usually kept. The punishment is now penal servitude for seven years, or imprisonment for two years. If the offence be committed in the uninclosed part of a forest, chace, &c., the penalty for the first offence is a sum not exceeding 50*l.*; and for a second offence, penal servitude or imprisonment.

Such are the principal legal provisions respecting game which exist at the present day. The right of appointing persons called gamekeepers, who are, properly speaking, a game police, does not belong to all owners of lands. Gamekeepers were first allowed to be appointed by 22 & 23 Car. II. c. 25. Before the act 1 & 2 Wm. IV. c. 32 was passed, a person could only appoint one gamekeeper. By this act lords of manors may appoint one or more gamekeepers to preserve or kill game within the manor for their own use. Lords of manors may depute any person to be a gamekeeper to a manor, with authority to kill game for his own use or that of any other person named in the deputation. The gamekeepers are authorised to seize all dogs, nets, and other engines used for killing game by uncertificated persons.

Until the passing of the act 1 & 2 Wm. IV. c. 32, no person was allowed to sell game; but it was made saleable by this act, as the law was systematically evaded. A dealer in game must obtain an annual licence from the justices, who hold a special session in July for the purpose of granting such licences. Innkeepers, victuallers, retail beersellers, guards, coachmen, carriers or higglers, or persons in the employ of any of these classes of persons, are prohibited from dealing in game. Licensed dealers who buy game of any person not authorised to sell it are liable to a penalty of 10*l.* with costs. A person not being licensed, who buys game of an unlicensed person, subjects himself to a penalty not exceeding 5*l.* for each head of game, with costs.

The preservation of game is an object of constant solicitude to nearly all those who belong to the landed gentry in this country. The pursuit of game is not only followed for the sport which it affords, but because ideas derived from the feudal times still attach a social distinction to the right of killing birds and beasts of game. Although a property qualification has been abolished, the privilege is still sufficiently restricted to confer upon those who enjoy it a petty importance. Within the last century game has been preserved to an excess which was previously unknown. Most of the laws relating to game which have been passed within this period have been made to enable game-preservers to indulge in this taste, and to visit with greater severity those who are tempted by the abundance of game to become poachers. The accumulation of game in preserves, watched and guarded by numerous keepers, has led to changes in the modes of sporting. The sportsman of the old school was contented with a little spoil, but found enjoyment in healthful recreation and exercise, and was aided by the sagacity of his dogs. In the modern system of battue-shooting, the woods and plantations are beaten by men and boys; attendants load the sportsman's guns, and the game is driven within reach of gun-shot, and many hundred heads of game are slaughtered in a few hours. The true sportsman would as soon think of spoiling a poultry-yard. Battue-shooting is the end of excessive game-preserving; and in this so-called sport, members of the royal family, ministers of state, and many of the aristocracy, eagerly participate. In an ordinary day's sport of this description, seven or eight hundred head of game may be killed by three or four sportsmen in about four hours, and perhaps fifty or sixty wounded may be picked up on the following day. A couple of gentlemen may kill nine hundred hares in one day. On a great field-day, when the sportsmen are more numerous, the slaughter is immense. Whole waggon-loads of hares are sent off to the London and other great markets for sale, as the result of one day's sport.

The effect of protecting game by oppressive laws is, perhaps, more injurious to the morals of the rural population than any other single cause. With a densely crowded population, thousands of whom are often pressed by hunger, and frequently in a state of the most lamentable poverty, the temptation to kill game is irresistible. It swarms before the labourer as he returns home in the evening from his long day of hard toil. *He* does not recognise property in game. No man can claim an individual hare or partridge like an ox or a sheep. The latter must be fed at the expense of their owners; but game is fed by no one in particular. This man, then, who probably would not, for all his poverty, violate the laws of property in the case of poultry, and who recognises no greater right of property in a partridge than in a sparrow, sets a snare in the haunts frequented by game near his cottage, and is pounced upon by the keeper. When he comes out of the jail, the farmers perhaps dare not employ him, lest they should offend the game-preservers their landlords. The justice and the rural police look upon the jail-bird with suspicion; and only at the beer-shop, with men of his own stamp and character, does he feel at home. It is hardly necessary to sketch his further progress. In nine cases out of ten, it is from bad to worse; and this because for objects of selfish gratification men have given to a bird or beast of little worth in itself an arbitrary value, and protected it by statutory regulations stricter than are applied to many other things which are recognised as objects of property by all mankind.

Jails require to be enlarged; and as poaching leads to other crimes, a more extensive police is required for the protection of property. The game laws are in this way a heavy burden on the occupiers of land.

Game, and the game laws, are among the greatest hindrances to the improvement of agriculture. They not only prevent a gain, but they occasion a loss to the actual aggregate of agricultural products.

Many landowners in their enthusiasm respecting game take means to ensure its preservation which none but tenants in a wretched state of dependence would submit to. The tenant is not allowed to use his best skill in the application of his own capital to the land, but is interfered with on account of the game. This game devours the produce of the land, is fattened at the tenant's expense (compensation for the destructiveness of game being generally futile and deceptive), and the landlord pockets the money which the game thus fed produces in the market. The effect would be far less injurious if the landlord turned a certain proportion of his oxen and sheep to feed with those which belong to his tenants. There are instances where the landlord lets the game on the tenant's land to a third person, and thus gets two rents, one for the land, and another rent for the game after it has been fed by the farmer.

It has often been stated, that from three to five hares eat and destroy as much as would keep one sheep. On many farms the number of hares averages at least two per acre; and the destruction by hares alone is often equal to an additional rental of 10*s.* per acre on the whole of the farm: there is, besides, the waste and destruction caused by rabbits, pheasants, and partridges. On some farms of 500 acres where the game is strictly preserved, but not excessively, the loss caused by hares will often amount to above 200*l.* The landlord sells the hares at perhaps 1*s.* 6*d.* each, and pockets 75*l.* This is shortsighted enough, setting aside the bad moral effect of the practice. The operations of the poacher, if he escape detection, are in one sense beneficial to the tenant-farmer, for the destruction of the game adds to the farmer's profit; but if the poacher be convicted and sent to jail, then the support of the man and his family adds to the loss which the game occasions.

Many of the reservations and covenants in leases in relation to game are fit only for the copyholders of a manor four or five centuries ago. There are many farms on which the tenants are forbidden either to mow wheat or drill turnips. Mowing costs less than reaping, and the tenant has besides the advantage of an extra quantity of straw for the stock and for manure; but then the ground is left too bare to shelter the partridges, and therefore the scythe must not be used, nor any other instrument which cuts lower than twelve inches. Drilling turnips is now an essential operation in all good systems of farming; but though it gives a much greater weight of roots per acre, it encourages the birds to run, and spoils sport. In some districts, where game is preserved with great strictness, a farmer is not allowed to sow winter tares. To drain land where rabbits are kept would be a waste of property. Legislation cannot produce any improvement in this state of things. It arises from the dependent condition of the great majority of the tenant-farmers; and if a law were passed which gave them the right to kill the game on their lands, it would be of no advantage to them. The gamekeepers and other retainers of the great and small game-preservers are spies on the tenant, and in the intense competition for farms he dare not contravene the wishes of his landlord. Public opinion may and does produce some effect on the landlord's exercise of his power, but this is confined to isolated cases.

The administration of the game-laws in England is in the hands of persons who are either game preservers themselves, or who, generally speaking, are not unfavourable to the system, and hence the rigour with which offences against the law are visited. Before the act 1 & 2 Wm. IV. c. 32 was passed, penalties for infractions of the game-laws could be recovered before one justice; but now conviction can only take place before two justices, and an appeal lies to the quarter-sessions, but a certiorari is not allowed.

The number of certificates taken out annually to kill game is about 30,000 in Great Britain, and the number of licences to sell game about 800.

In other countries, as well as in England, game-laws have been an instrument of oppression. In France before the first Revolution there were edicts for preserving game which "prohibited weeding and hoeing, lest the young partridges should be disturbed; steeping seed, lest it should injure the game; manuring with night-soil, lest the flavour of the partridges should be injured by feeding on the corn so produced; mowing hay, &c. before a certain time, so late as to spoil many crops, and taking away the stubble which would deprive the birds of shelter." ('Arthur Young's Travels in France in 1787-88-89.') The tyranny of the manorial courts rendered it hopeless to escape from this oppressive system. The Constituent Assembly abolished this exclusive "droit de la chasse" which the seigneurs arrogated to themselves. A stringent game-law has nevertheless been since enacted in France.

GAMING, or GAMBLING, is an amusement,—or we might properly call it a vice,—which has always been common in all civilised countries and among all classes, but more particularly the rich and those who have no regular occupation. But a passion for gaming is not confined to the nations called civilised: wherever men have much leisure time and no pursuit which will occupy the mind and stimulate it to active exertion, the excitement of gaming, which is nothing more than the mixed pleasure and pain arising from the alternations of hope and fear, success and failure, is a necessity which all men feel, though in different degrees according to the difference of temperament. The Germans, says Tacitus, stake their own persons, and the loser will go into voluntary slavery, and suffer himself to be bound and sold, though stronger than his antagonist; and many savage nations at the present day are notoriously addicted to gambling.

Gaming (*alea*) among the Romans was played with dice. The earliest enactment against it is referred to by Plautus and Cicero; but it is not certain what the penalty was. Under the later republic and the empire gaming was a common vice, but it was considered to be disreputable. The little that is known of the penalties against gaming is contained in the Digest (11, tit. 5) and the code of Justinian (iii. tit. 43). The prætor in this, as in many like cases, placed the encourager of gaming under disabilities. If a man lent his house for gaming, and, while the gaming was going on there, was beaten or had anything stolen from his house, the prætor refused him all remedy. A senatusconsultum, the name and time of which are not mentioned, prohibited all playing for money, except the stake was made upon the five athletic exercises enumerated, and, as we must infer, by the persons who joined in the exercises. If a slave, or a son in the power of his father, lost money at gaming, the father or owner of the slave might recover it. If a slave won money, there might be an action for it against the master; but the demand against the master could not exceed the amount of the slave's peculium,—that is, the property which the slave held as his own, according to Roman custom, with the permission of his master. The prætor's edict also allowed an action against parents and patrons in respect of money lost (to children or the patrons' freedmen, as we must understand it). Justinian made several constitutions against gaming. A man who lost money at gaming was not bound to pay it; and if he did pay, it could be recovered by him or his successors (in the Roman sense) from the winner or his heredes any time within thirty years. If they did not choose to recover it, the father or defender (defensor) of the town in which the money was lost might recover it, or any other person might. The money, when recovered, was laid out for public purposes. Gamblers were also liable to a fine. Spiritual persons who violated the gaming laws, or were present at gambling, were suspended for three years and confined in a monastery. ('Novell.' 123, c. 10.)

In England, gaming was very early the subject of penal enactments, but as a proof how futile legislative measures may be, we need only mention, and we do so without fear of contradiction, that there are, or at least were, until recently, more of those infamous places of resort, appropriately denominated "hells" in London, than in any other city in the world. The handsome gas lamp and the green or red baize door at the end of the passage (as well known a sign as the Golden Cross or Spread Eagle) were recently conspicuous objects in the vicinity of St. James's, and of St. George's, Hanover Square.

It appears that the playing at cards, dice, &c., was not punishable at common law; and an action might be maintained at law for money won at play; for the contract was not void in itself, and the winner's venturing his money was a sufficient consideration to entitle him to the action.

But if a person was guilty of cheating, as by playing with false dice, cards, &c., he might be indicted for it at common law and punished by fine or imprisonment (2 Bac. Abr. 620). All common gaming-houses were nuisances in consideration of law. By the statute of 33 Hen. VIII., c. 9, "no person shall for his gain, lucre, or living, keep any common house, alley, or place of bowling, coyting, cloyth, cayls, half-bowl, tennis, dicing-table, carding, or any unlawful game, then or thereafter to be used, on pain of forfeiting 40*s.* a day;" and the same statute enacted that *every* person haunting and using the said houses, and playing, shall forfeit 6*s.* 8*d.*

By 16 Charles II. c. 7, any person who won any sum of money by fraud, cosenage, or deceit, was to forfeit treble the value won. Under the statute 8 & 9 Vict. c. 109, repealing the statute of Henry VIII. so far as relates to the prohibition of games of skill therein mentioned, together with the statutes of Charles II., and Anne, and several others, cheating at play is punished as obtaining money under false pretences.

By 9 Anne, c. 14, any person who "at any *one time or sitting*, by playing at cards, dice, or *other game whatsoever*, or by betting on the sides of such as do play," *lost* to any one or more persons, in the whole the sum or value of 10*l.*, and paid the same or any part thereof, might within three months sue for and recover the same in any court of record, and after three months any other person might sue for and recover the same and treble the value thereof, with costs of suit. It is curious that gambling in the palace where the sovereign is residing for the time being is excepted from the statute of Anne.

An act 5 & 6 Wm. IV., c. 41, repealing several old statutes, altered the law relating to securities given for gaming transactions. It enacts that in case any person shall make, draw, or execute, any note, bill, or mortgage for a gaming debt, and shall actually pay to any indorsee, holder, or assignee of such note, bill, or mortgage, the sum thereby secured or any part thereof, such money shall be deemed to be paid on account of the person to whom such note, bill, or mortgage was originally given (upon the illegal consideration), and shall be deemed to be a debt due from such last-mentioned person to the person who shall so have paid such money, and shall be recoverable by action at law in any court of record.

The acts 8 & 9 Vict. c. 109, and 17 & 18 Vict. c. 38, greatly facilitate proceedings against any common gaming-house. The first mentioned statute enacts that in default of other evidence it shall be sufficient to prove that a house or place is kept or used for playing therein at any unlawful game, and that a bank is kept there by one or more of the players exclusively of the others, or that the chances of any game played therein are not alike favourable to all the players, including among the players the banker or other person by whom the game is managed, or against whom the other players stake, play, or bet; and every such house or place shall be deemed a common gaming-house. It is not necessary under this act to prove that any person found playing at any game was playing for any money, wager, or stake. The act dispenses with the necessity of obtaining the allegation of two householders that any house is a common gaming-house; and empowers justices of the peace in places beyond the metropolitan police district, to authorise constables, and commissioners of police, within such district, to authorise superintendents by a written order to enter any suspected house or room with constables, and, if necessary, to use force for the purpose of effecting such entry, whether by breaking open doors or otherwise, and to take into custody all persons who shall be found therein, and to seize and destroy all tables and instruments of gaming found in such house or premises, and also to seize all money and securities for money found therein. If any cards, dice, balls, counters, tables, or other instruments of gaming used in playing any unlawful game be found in any house or room which the police have entered as a suspected gaming-house, or about the person of any of those who shall be found therein, it is evidence, until the contrary be made to appear, that such house or room is used as a common gaming-house, and that the persons found in the room where such instruments of gaming shall have been found, were playing therein, although no playing was actually going on in the presence of those who made the entry. Before this act was passed, persons found in a gaming-house could not be searched; and proof of play was necessary before entry. Notwithstanding this act, the keepers of gaming-houses contrived by fortifying the entrances, and by other means, to keep out the officers of justice until the instruments of gaming were removed or destroyed, so that no sufficient evidence could be obtained to convict the offenders. To render the law more efficient in this and other respects, the act 17 & 18 Vict. c. 38, was passed (1854), by which penalties and imprisonment was imposed on persons obstructing the duty of constables, and obstructing their entry made evidence of the house being a common gaming-house. Persons who have been concerned in unlawful gaming and who give evidence on the trial of any owner or keeper or person who has had the management of a common gaming-house, may obtain a certificate from the magistrate or judge of the court, which frees them from all criminal prosecutions, penalties, &c.

The punishment which may be inflicted on gaming-house keepers is, a penalty not exceeding 500*l.*, or imprisonment with or without hard labour for a term not exceeding twelve months.

By 8 & 9 Vict. c. 109, public billiard and bagatelle boards are not to be kept without a licence, and the places where they are kept may be visited at any time by constables and officers of police; and such places are to be closed entirely on Sundays, and on other days at midnight, except Saturday, when the hour of closing is fixed at eleven o'clock.

Gambling is nevertheless carried on in the metropolis at those places where billiard-tables are kept, at public-houses, and also at cigar-shops. The evidence taken before the select committees on gaming in 1844, contains a mass of information on the subject of gaming and gambling both in London and elsewhere.

In England, before the passing of 8 & 9 Vict. c. 109, the law considered wagers in general as legal contracts, and the winner of a wager could enforce his claim in a court of law. The exceptions to this rule were, where the wager was an incitement to a breach of the peace or to immorality; where it affected the feelings or interests of third persons, or exposed them to ridicule or inconvenience; or where it was against sound policy or prohibited by statutory enactment. In cases not comprehended within the above exceptions, the judges frequently refused to try actions respecting wagers, when they considered the matter to be of a frivolous or of an improper nature.

In Scotland the courts followed an opposite rule to that which prevailed in England. They held that "they were instituted to try adverse rights, and not to determine silly or impertinent doubts or inquiries of persons not interested in the matters in question;" and they decided "that their proper functions are to enforce the rights of parties arising out of serious transactions, and not to pay regard to *Sponsiones ludicræ.*"

The provisions of the statute of Anne, so far as they applied to bets exceeding 10*l.*, was so much a dead letter, that its existence appears to have been almost forgotten, until in 1843 a number of actions were brought by common informers against several noblemen and gentlemen who had violated the law by betting sums of more than 10*l.* on horse-races. A bill was brought in for the relief of these persons, and was rapidly passed through its several stages. Select committees were appointed in both Houses of Parliament to inquire into the laws respecting gaming, and another act (7 Vict. c. 7) was passed to indemnify witnesses implicated in gaming transactions who should give evidence before these committees.

The committee of the House of Commons, in 1844, on gaming, recommended that "wagering in general should be free and subject to no penalty;" and they also expressed an opinion in favour of the law of England being assimilated to that of Scotland.

In the session of 1845 the act 8 and 9 Vict. c. 109 was passed, which enacts "That all contracts or agreements, whether by parole or in writing, by way of gaming or wagering, shall be null and void; and that no suit shall be brought or maintained in any court of law or equity for recovering any sum of money or valuable thing alleged to be won upon any wager, or which shall have been deposited in the hands of any person to abide the event on which any wager shall have been made: provided always, that this enactment shall not be deemed to apply to any subscription or contribution, or agreement to subscribe or contribute, for or toward any plate, prize, or sum of money to be awarded to the winner or winners of any lawful game, sport, pastime, or exercise."

The act 8 & 9 Vict. c. 109 repealed those parts of 9 Anne c. 14, and 18 Geo. II. c. 34, which rendered it illegal to win or lose any sum exceeding 10*l.* at play or by betting.

By 5 Geo. IV., c. 83, persons betting, &c. in any street or open and public place, are punishable summarily as rogues and vagabonds.

By the 10 & 11 William III. c. 17, lotteries were declared public nuisances, and by several subsequent acts they have been prohibited under various penalties.

The act 7 Geo. II. c. 8, which was made perpetual by 10 Geo. II. c. 8, entitled "An Act to prevent the infamous practice of stock-jobbing," is violated hourly on the London Stock-Exchange by the practice of time-bargains.

The acts 19 Geo. II. c. 37, and 14 Geo III. c. 48, are intended to prevent transactions of the nature of gaming or wagering on policies of marine and life insurance.

It was enacted by the 13 Geo. II. c. 19, that no horse-race should be run for any prize of less than 50*l.* in value; and any wager on a horse-race made illegal by this statute was illegal also; but this provision was repealed by the 3 & 4 Vict. c. 5. The effect of the repeal of the provisions of this statute, and of the 33 Hen. VIII. c. 9, combined with the exception in the 8 & 9 Vict. c. 109, was to place all bargains relating to horse-racing on the same footing as other contracts. No sooner, however, were contracts as to horse-racing legalised, than a great number of petty gaming-houses sprung up, under the name of "betting-offices." The demoralisation which was found to be the immediate result called for the interference of the legislature, and the stat. 16 & 17 Vict. c. 119 was accordingly passed, expressly for the suppression of these haunts of vice.

It may be observed that, under the Bankrupt Laws, a bankrupt is not entitled to a certificate, or the certificate if granted is void, if he has lost 20*l.* in one day, or 200*l.* in a year, by any sort of gaming or wagering. (Kerr's 'Blackstone.')

In France, and many other parts of the Continent, the government not only allowed, but derived a considerable revenue from games of chance. In Paris, the *exclusive* right of keeping public gaming-houses was, until the year 1838, let out to one company, who paid an annual sum of 6,000,000 francs (about 240,000*l.*) for the privilege. They kept six houses, namely, Frascati's, the Salons, and four in the Palais Royal. In a trial in Paris, it came out in the course of the evidence, that the *clear profit* for 1837, exclusive of the duty, had been 1,900,000 francs (76,000*l.*), of which three-fourths was paid to the city of Paris, leaving the lessee 19,000*l.* for his own share. The average number of players per day was stated at 3000, and about 1000 more were refused admittance. The games played were chiefly Roulette and Rouge-et-Noir, of which the latter is the favourite. It is very seldom that large sums are staked at the former, as the chances against the player are considered immense by *professional* men, a class of gentlemen who are gamblers by profession. Rouge-et-Noir is played with four packs of cards, and the "couleur" which is nearest 31 wins; the black being dealt for first, and then the red. All the houses were open from one o'clock in the afternoon till one or two after midnight; and latterly till five or six in the morning. The highest play, especially at Frascati's, was carried on between three and six in the afternoon. Ten or twelve thousand francs were constantly lost at a sitting, and once 100,000 francs, which constituted the "Banque" of the day, was won by a French nobleman. The actual chance of the table or "Banque" is considered to be 7½ per cent. above that of the player, supposing the game to be fairly played, as it no doubt was in Paris under the old system; the cards being examined and stamped by the government, and there being an agent of the police always present and ready to detect any attempted fraud on the part of the company. But admitting the game to be fairly played, the coolness of the "croupiers" or dealers, who had no interest at stake—the whole of the losses or gains being taken by the company,—and the large capital of the latter, made it absolutely impossible for the player to win in the long run; nay, it is clear that he must lose, and that in proportion to his stake, which probably is regulated by his means. This we have heard admitted by the most constant frequenters of these houses; and nevertheless, under the influence of those causes which first lead men to gaming, confirmed by habit and example, they still continue to indulge their passion till they are reduced to beggary, which is often followed by suicide.

That a vice which causes so much wretchedness should not merely be permitted and the practice of it superintended by the government, but that it should contribute considerably to the public revenue, was a subject of loud complaint in France; and at last the ministers, in compliance with the desire of the Chamber of Deputies, determined to grant no more licences after the 1st of January, 1838.

In most parts of Germany gaming is allowed; and the magnificent saloons set apart for roulette and rouge-et-noir at Baden, Wiesbaden, and other German watering-places, are well known to English travellers on the Continent. The respective sovereigns of the states in which these fashionable gaming-places exist derive an immense revenue by letting the exclusive privilege of keeping gaming establishments; and we may frequently see the grand duke or prince playing at the table of his lessee, and losing a considerable portion of what he receives for granting the privilege.

In Italy and Spain gambling is a very common vice, especially among the lower orders, and you scarcely can find a muleteer, porter, or shoe-black, who has not a pack of dirty cards in his pocket, which he pulls out whenever he has a moment's leisure; and should he not be lucky enough to find a partner who will risk his money against him, he will frequently give a boy a trifle to play with him.

In the United States of America, but more particularly in the Southern States, the practice of gambling is very common, though restrained, as we believe, in all the States by legislative enactments.

The following abstracts of the laws relating to gaming in different countries were prepared by J. M. Ludlow, Esq., and were laid before the Select Committee of the House of Commons on gaming, by H. Bellenden Ker, Esq.:—

By the French law, as it stood before the Revolution, minors alone could recover their losses at play; but no winnings could be sued for except in the case of warlike sports; when not excessive, games of strength and skill were permitted, games of mere chance absolutely forbidden.

The Code Français allows an action for money won at games of strength and skill, when the amount is not excessive; but money paid can never be recovered, unless on the ground of fraud. The keepers of gaming-houses, their managers or agents, are punishable with fine (100 to 6000 francs), and imprisonment (two to six months), and may be deprived of most of their civil rights. A trifling fine is imposed on those who set up lotteries, or games of chance in public places; the furniture, implements, &c. are in all cases to be seized.

By the Prussian Code all games of chance, except when licensed by the state, are prohibited. Gaming debts are not the subject of action; but money paid cannot be sued for by the loser. Wagers give a right of action when the stakes are constituted in cash in the hands of a third person; they are void when the winner had a knowledge of the event, and concealed it. Money lent for gambling or betting purposes, or to pay gambling or betting debts, cannot be sued for. Gaming-house keepers are punishable with fine, professed gamblers with banishment; and if they break the ban, by imprisonment. Occasional cheating at play obliges to compensation; professed swindlers at play are punishable as for theft, and banished afterwards. Money won from a drunken man, if to a considerable amount, must be returned, and a fine paid of equal value.

In Austria no right of action is given either to winner or loser. All games of chance are prohibited, except when licensed by the state. Cheating at play is punishable with imprisonment, according to the amount of fraudulent gain. Playing at unlawful games, or allowing such to take place in one's house, subjects the party to a heavy fine, or in default to imprisonment.

The provisions of the Sardinian civil code are similar to those of the French, giving an action for money won at games of strength or skill, when not excessive in amount; but not allowing the recovery of money lost, except on the ground of fraud or minority (a provision taken from the old French law).

The Bavarian code is somewhat special in its provisions; it distinguishes between games of pure skill, and mixed skill and chance on the one hand, and games of mere chance on the other. In the two former, money honestly won, and not excessive in amount, may be lawfully claimed, and money lost cannot be recovered; but with respect to fraudulent or excessive gaming, and also as to all games of mere chance, the winner may be called upon to repay his gains, and is liable, together with the loser (except as to the latter, in the case of fraud), to a penalty of varying amount. Gaming-house keepers and professed gamblers are subjected to various penalties. Distinctions are also taken as to wagers, which are only void for fraud or immorality, but the amount of which is liable to be reduced, if excessive. When money lost at play is proved to have been the property of some other person than the player, the true owner may recover it.

Wagers also appear to be lawful in Spain, when not in themselves fraudulent or relating to anything unlawful or immoral. (Johnson's 'Institutes of the Civil Law of Spain,' p. 242.)

GAMMUT, in Music, signifies, in the popular sense of the word, the *diatonic scale*, as named either by the seven first letters of the alphabet, or by the syllables used in solmisation, that is, *do*, *re*, *mi*, *fa*, *sol*, *la*, *si*. [DIATONIC SCALE.] And occasionally the term is applied to a single note—the G below the base clef. The word is compounded of the name of the third letter in the Greek alphabet, Γ (gamma), the final vowel being cut off, with the syllable *ut* added. In the 11th century the ancient scale was extended by the addition of a note below that sound which the Greeks called *proslambanomenos* (that is, supernumerary), the latter answering to our A, the first space of the base staff, and the note was called *Gamm'-ut*,—that is, G *ut*, or G *do*.

The invention of the gammut in its antiquated form is generally ascribed to Guido d'Arezzo, but it now seems nearly certain that in part, if not wholly, it existed much earlier than his period. It long continued in use, and was one of the many stumbling-blocks in the path of musical students. Happily little more than the name remains; it is therefore unnecessary for us to enter further into the subject.

GAOL. [PRISON; PENAL SERVITUDE.]

GAOL DELIVERY. The commission of gaol delivery is directed to the justices of assize of each circuit, the serjeants and queen's counsel attending that circuit, the clerk of the assize, and the judges' associate. It is a patent in the nature of a letter from the sovereign, constituting them his justices, and commanding them, four, three, or two of them, (of which number there must be *one* at least of the judges and others specified) to deliver his gaol at a particular town of the prisoners in it; it also informs them that the sheriff is commanded to bring the prisoners and their attachments before them at a day to be named by the commissioners themselves. Under this commission the judges may proceed upon any indictment of felony or trespass found before other justices against any person in the prison mentioned in their commission and not determined, in which respect their authority differs from that of justices of oyer and terminer, who can proceed only upon indictment found before themselves. (2 Hale, P. C.) [ASSIZE.]

Anciently it was the course to issue special writs of gaol delivery for each prisoner, but this being found inconvenient and oppressive, a general commission has long been established in their stead. (4 Bl. 'Com.;' Hawk, P. C.)

GARANCIN. [MADDER, *colouring matters of.*]

GARDEN. A garden, as distinguished from a farm, is a piece of ground designed for the cultivation of plants not actually indispensable to man for food. While corn for flour, various roots and herbs for the sustenance of cattle, or tracts of pasture land on which animals destined for slaughter are maintained, constitute the essential features of a farm; a garden, even when exclusively occupied by culinary vegetables, is still a source of objects of luxury, not of first necessity. In a more extended sense, and as it usually exists at the present day, it is chiefly intended to gratify the senses and to minister to the more refined enjoyments of social life.

The possession of a garden is one of the most early indications of civilisation in man, and it is only among the most brutal and degraded races of savages that it is altogether unknown; while we find such an appendage to a dwelling increased in magnificence, or diminished and neglected, with the prosperity or decline of the most mighty states. It is Lord Bacon who says that "when ages do grow to civility and elegancy, men come to build stately sooner than to garden finely, as if gardening were the greater perfection."

According to Sir John Malcolm, the Persians had gardens from the period of their first king Mahabad. We learn from Xenophon that Cyrus considered them an indispensable appendage of his residences. "Wherever he resides, or whatever place he visits in his dominions, he takes care that the *paradises* shall be filled with all that is beautiful and useful which the soil can produce." ('Cyropæd.' v.) And it appears upon the testimony of Pliny and other Roman authors, that among the same people small gardens existed, in which trees were arranged in straight lines and regular figures, the margins of the walks being planted with tufts of roses, violets, and other odoriferous flowering plants, while the trees consisted of kinds grateful for their fragrance, as the cypress and the pine, or agreeable for their shade, as the plane and the common elm. The Greeks, in their most flourishing times, appear to have been equally attached to the formation of gardens, and even, in some respects, to the nicer parts of the art of gardening. The Oriental narcissus, violet, ivy, and rose, are mentioned as their favourite flowers, and terebinthinous trees as those which were chiefly valued for their fragrance. The rich and polished Athenians are represented by Mr. Meason as having borrowed their gardening from Asia Minor. Myrtles and roses, the box and the lime-tree, were planted for clipping into artificial forms, while flowers and fruits were cultivated in the winter, and the violet was in profusion in the Athenian markets when snow was lying on the ground.

Theophrastus himself not only gives directions for gardening operations, many of which were fanciful enough, such as sowing rue with chips of fig-wood, and pulling up esculents by way of making them more tender, instead of cutting them; but he had a garden of his own which he left to ten of his friends to be preserved as a place of public resort for those who employed their leisure in letters and philosophy. (Diogen. Laert., v. 53.) The instances of the kings Attalus Philometor [ATTALUS, in BIOG. DIV.] and Mithridates, who cultivated all sorts of poisonous plants in their gardens, are perhaps the earliest upon record of such places being occupied for medical purposes.

It is not to be supposed that gardens were neglected by the luxurious and wealthy Romans. The prodigious gardens of Lucullus, who introduced the cherry, the peach, and the apricot from the Persians, were derided by his Roman friends for their extraordinary sumptuosity. They are related to have consisted of immense artificial towers, large sheets of water, gigantic edifices jutting into the sea, and mountains raised where no hill had existed before. Such an example might be ridiculed by some, but was certain to be followed by others whose taste for splendour and profusion was supported by unbounded wealth; and, accordingly, the gardens of Sallust, of the emperors Nero and Hadrian, and of many of their subjects, are doubtless to be classed in the same order as those of Lucullus. It is, however, to be remembered, that such gardens were rather more similar to an English park and garden combined than to a mere garden, in the modern sense of the word, and moreover were so uncommon as to be looked upon with wonder by the people among whom they were created. A common Roman garden must have been a very different place, if we are to take the description given by Virgil ('Georgic.,' iv. 121) as at all a faithful sketch; for he speaks of nothing but endive (intyba), celery (apium), melons? (cucumis), narcissi, acanthus, roses, ivy, and myrtles. That they had various trees bearing fruit, as well as the common wild timber of the country, and many different kinds of flowers, must of course be admitted; but that all gardens, up to the most flourishing period of the Roman empire, must have been much alike as regards the plants they contained, is manifest from the fact that hardly more than seventy plants of all descriptions are noticed by this poet, although he wrote professedly upon rural affairs. It is true that the Romans carried their passion for flowers so far that it became necessary to restrain it by sumptuary laws, and that cases of extreme profusion in the use of them are mentioned by historians. The institution of Floralia, or flower-feasts, the universal passion for garlands, the reproaches addressed by Cicero to Verres for having made the tour of Sicily in a litter, seated on roses and decked with festoons of flowers, are a sufficient evidence of this taste having been carried to an extent unknown at the present day; to say nothing of the prodigality of Heliogabalus, or of Cleopatra, the latter of whom is said by Athenæus to have paid upwards of 200*l.* (an Egyptian talent) for roses expended at one supper. But notwithstanding this, the variety of plants that were cultivated in the gardens of both Greeks and Romans must have been extremely small. Theophrastus speaks only of roses, gillyflowers, violets, narcissi, and iris, as used for decoration, to which the larkspur and gladiolus (hyacinthus), with the white lily, and a few others, may be added. The great object of their admiration was roses, which were forced by plates of talc (said to have been as much as five feet long; but it is more probable that these *specularia* were sashes five feet long, glazed with talc) being placed over bushes watered with warm water. Pliny, in his 'Natural History,' does not enumerate above 1000 plants of all descriptions,—a very small part of which were objects of cultivation. At the fall of the Roman empire the following appear, from Mr. Loudon's statement, to have been the principal garden plants, exclusive of common trees and flowers. 1. *Culinary plants:*—peas, beans, vetches, lentils, kidney-beans, gourds, cucumbers, melons, cabbages of many sorts, turnips, carrots, parsnips, beet, skirret, radishes, sorrel, asparagus, onion, garlic, and other alliaceous plants, endive, lettuce, succory, mustard, and other salads, parsley, celery, orach, alexanders, elecampane, fennel, chervil, and some others. 2. *Fruits:*—fig, almond, citron, peach, pomegranate, apricot, plums, and cherries; twenty-two sorts of apples, thirty-six sorts of pears, services, quinces, and medlars; many kind of grapes, mulberries, nuts, walnuts, chesnuts, stone-pines, or pignons, olives, and carobs. They forced flowers with sashes of talc, as has already been noticed, and also cucumbers; it is probable that they extended this practice even to fruits.

With the fall of the Roman empire the art of gardening seems to have been lost, and it was not till a long time after that gardens are again heard of. It was among the monks that the arts of cultivation were preserved, and in connection with monastic institutions gardens again became matter of history. In these religious institutions, which were in many respects the only spots where the arts of peace could find shelter during ages of rapine and violence, gardens continued to be cherished; and although the ignorance of the monks prevented their being rendered so useful as they might have been, yet, on the other hand, their sacred protection opposed an effectual barrier to the wild progress of destruction.

Among his many reformations, the re-establishment of gardens formed part of the policy of the emperor Charlemagne, who introduced the subject into his *capitularies*, commanding gardens to be formed throughout his dominions, and prescribing the very plants which were to be cultivated therein: and considering the state of learning in those days, it must be admitted that the list, short as it is, was prepared with good judgment; for it was made to contain the most useful plants then known for diet or medicine, as well as the favourite ornamental flowers of the Romans. The reader of the present day may be amused at the list of what was thought in the 8th century deserving of an imperial edict, at a time when no one had heard of a garden except within the walls of a castle or a monastery (*Walafridi Strabi Hortulus*):—Roses, lilies, fenugreek, costmary (*Costus*), sage, rue, southernwood, melons, gourds (*Cucurbitæ*), water melons (*Pepones*), kidney beans, cummin, rosemary, caroway, lentils, squills (?), gladiolus, tarragon, cucumbers (*Coloquintida*), heliotrope, (*Ammi majus*, *Sium angustifolium*), lettuce, nigella sativa, rocket (*Eruca*), nasturtium, dock, alexanders, parsley, celery, savin, fennel, dittany, woodmint, watermint, catmint, centaury, beet, marsh mallows, carrot, orach (*Adripia*), kohl rabi, chives, radishes, onions, madder, beans, chervil, clary, lovage, anise, succory, mustard, savory, mint, tansy, poppy, asarabacca, hollyhocks, parsnip, blite, cabbage, leeks, rocambole, garlic, teasel, peas, euphorbia lathyris (*Lacterula*), houseleek. From this proceeding of Charlemagne the revival of gardens may be said to date, for although there are few direct traces of their existence for some centuries, yet there is no reason whatever to suppose that they were ever again lost sight of. In the 14th century we find Matthæus Sylvaticus, a Mantuan physician, speaking of his own garden, and of a Colocasia cultivated in his greenhouse on the edge of a beautiful fountain, and of a plant called Cantalis, supposed to be Athamanta cretensis, which he says he brought out of Greece and planted in his garden. ('Pandect.,' c. 197, 133.) It was however in Italy that the formation of gardens received a fresh impulse. Alfonso d'Este, duke of Ferrara, is recorded to have founded several botanic gardens in the 16th century, and especially one called Belvedere, surrounded by the water of the Po. The example was followed by several nobles of Ferrara; John Brasavolo, the uncle of the botanist Musa Brasavolo, had a viridarium or greenhouse; another noble, of the name of Acciajuoli, had many rare plants in his garden; and the collections of this city, augmented annually by the commerce of its merchants with Greece and Asia, became so rich in new exotic plants as to become celebrated all over Europe. The Ferrara gardens were soon rivalled by those of the Venetians and Paduans, one of whom, Gaspard de Gabrichis, is said to have spared no expense to enrich his garden, not with costly edifices and vast architectural embellishments, but with plants before unknown. (Spreng. 'de R. H.' iv. c. 3.) The greatest and earliest garden however of this era is generally considered to have been that founded at Pisa, in 1544, by Cosmo de' Medici, on the banks of the Arno; which by the year 1555 had become so rich in plants by the exertions of Lucas Ghini and his successor Cæsalpinus, as to have been the admiration of Belon, no mean judge. Haller indeed is of opinion that a greenhouse built by the bishop of Acquapendente dates from the year 1533, but this is at variance with the statement of Tiraboschi, who fixes the erection in the year 1545. Be this as it may, it is at least certain that about this period a public garden was formed at Bologna, others at Lucca, Naples, and Florence; and that at Verona one Cæsar Niclesola had two large greenhouses in which some very rare plants were preserved. (Pona, 'It. Bald.' p. 9.)

At this time Paris possessed no garden for its university; that of Montpellier had, however, been founded by Henri IV., and contained before the end of the 16th century upwards of 1300 French, Alpine, and Pyrenean plants, according to Olivier de Sevres ('Traité d'Agricult.,' 1600), and a famous garden had been created at Mans by Renate Bellaye, bishop of that city. In Germany too, the garden of Breslau, to which Tragus and Fuchs were attached, of Basel, Strasburg, and other places, were at this time in existence, and the since celebrated garden at Leyden had been founded in 1577, at the instance of Gerard Bontius.

The principal part of these establishments were founded for academical purposes; when they were formed for private gratification their owners must be considered very much in advance of their times, if we are to form an opinion from the state of private gardening in this country at the same period. Here the only purpose contemplated in the formation of a garden appears to have been an enclosed place in which the owner might walk in seclusion, or in which sport might be had with contrivances like mazes and labyrinths formed of close-cut hedges; a few fruit-trees were added; but no such object as that entertained by the refined Italians, of collecting rare and beautiful plants from foreign countries for pleasure or for scientific purposes, was thought of. In the gardens of Nonesuch, the palace of Henry VIII., executed about the year 1540, we hear of shady walks, columns and pyramids of marble, "fountains that spout water one round the other like a pyramid, upon which are perched small birds that stream water out of their bills," and of similar objects, but nothing of the more essential part of a garden—its plants. Pleasure-grounds of this description had existed in England from the time of the Conqueror. It is stated by Fitzstephen that in the time of Henry II. (1154—1189) the citizens of London had large and beautiful gardens to their villas. In the reign of Edward I. (1272—1307) it may be collected from 'Holinshed's Chronicle,' that the cultivation of the garden was extended to the more curious and delicate productions; but the wars of York and Lancaster destroyed all these occupations, and gardens in general ceased to be more than pleasure-grounds or kitchen-gardens of the rudest kind till the time of Elizabeth. King James I. of Scotland describes the garden at Windsor Castle, where he was confined by Henry V., as a place set thick with trees, and alleys of hawthorn hedges, with an arbour in each corner,—

> "And myddis every herbore might be sene
> The scharp green swete jenepere."—*The Quair.*

Much later (1512) the great Earl of Northumberland, whose household consisted of 160 persons, had but one gardener, who attended hourly in the garden "for setting of erbis and clipping of knottis, and sweeping the said garden clean." Nay, it should seem as if sometimes there was not even one; for among the workmen of the household is mentioned the gardener of the place where my lord lyeth, *if there be one.* (Loudon.)

In these remarks all reference is omitted to the gardens of the Arabs; about which almost nothing is known, but which seem to have been more deserving historical record than those of other contemporary nations. That this people in the height of their power paid great attention to botany, is well known to those who are familiar with that science. A learned work on rural affairs was written in the 12th century by Abu Zachariah Ebn Alva, a native of Seville, of which an epitome has been given by Casirius ('Bibl. Escurial,' i. 326, s.); and according to Mr. Loudon, this writer has left a list of plants cultivated in the garden of Seville, more extensive than that of the Greeks and Romans. In the 13th century the then Vizir of Cairo, Ebn-Beitar, a native of Malaga, was so much attached to botany that he visited all parts of the East for the express purpose of extending his knowledge of plants. His works are preserved in MSS. in the library of the Escurial, and it is said that although he scrupulously abstained from describing anything which he had not seen, yet he speaks of 2000 species more than Dioscorides. (Spreng., i. 238.) It is only reasonable to suppose that such a man had a garden. We must, however, fix the period when gardens first began to be extensively improved, in the middle of the 16th century, when, as has been already shown, the rich Italians turned their attention to the introduction of new and rare plants. By the time that this new taste began to be fixed in the minds of Europeans, the numerous geographical discoveries that had been made by the Portuguese and Spaniards, had opened new and unheard-of sources from which the lovers of gardens were able to enrich them. It would appear that the maize, the yam, tobacco, and the cotton-tree (*Bombax*) were brought to Europe by the Spaniards so early as the end of the 15th century (Barcia, 'Hist.' i. 24), and King Ferdinand is recorded to have preferred the pine-apple, brought home in Columbus's second voyage, to all other fruits. (Petr. Martyr. 'Reb. Oc. Dec.' l. 2, b. 39.)

It would be impossible to trace the progress of public taste in the construction of gardens any farther historically, without occupying more space than such a subject can have allotted to it in a work of this description. It may easily be conceived that from the time when the taste for gardens revived, up to the present period, there has been a gradual improvement in such places, commensurate with the wealth of individuals and the commercial power of nations, their peaceful habits, the security of property, and their general progress in settling the relations of social life. In the remainder of this article we shall offer a few remarks upon the most important causes which have contributed to bring gardens to their present improved condition, and conclude by a brief account of some of the most remarkable Botanical Gardens of the present day.

The first great step that was made by gardeners to advance their art beyond mere mechanical operations, was the invention of glasshouses, in which plants might be grown in an artificial climate, and protected from the inclemency of the weather. Until this was effected, it is obvious that the cultivation of exotic plants in Europe, especially its northern kingdoms, must have been much circumscribed. Mr. Loudon refers the invention of greenhouses to Solomon de Caus, architect and engineer to the Elector Palatine, and who constructed the gardens at Heidelberg in 1619. But there can be no doubt that buildings of this description claim a higher antiquity. The specularia of the Romans, whether pieces of talc 5 feet long, or, as we rather suppose, sashes 5 feet long glazed with talc, were certainly used for the purpose of forcing roses and some other plants; they were essentially greenhouses, although perhaps more like our garden-frames. It is scarcely likely that where gardening survived, the learned men, in whose hands all such subjects then were, should have been unacquainted with the existence of these specularia, and they would naturally endeavour to reconstruct them. Greenhouses certainly existed among the Italians in the middle of the 16th century, as has been already mentioned, and there is no reason to suppose they had then for the first time been thought of. In fact, the ancient viridarium seems to have been a room with one side of it glazed with sashes reaching from the top to the bottom, and resembling the old English conservatory. It may or may not have been heated; probably not, for it was chiefly Greek, Egyptian, and Levant plants that were at first cultivated as rarities by the wealthy Italians, and they required no artificial heat in Italy.

If heat were required, it would be supplied by stoves or such other contrivances as were used for domestic purposes. Ray says, that in 1684 the greenhouse in the Apothecaries' garden at Chelsea was heated by means of embers placed in a hole in the floor: and it appears, from a section of a greenhouse in the Electoral garden at Manheim, published in 'Medicus Index Plantarum,' that a German stove was used there as late as 1771. We however agree with Mr. Loudon in considering the invention of *glass-roofs* for greenhouses to be an æra from which the principal part of modern improvements takes its date. This happened in 1717, when Switzer published the plan of a forcing-house, suggested by the Duke of Rutland's graperies at Belvoir Castle. Up to that time the want of light must have rendered it impossible to employ greenhouses for the growth of plants, either in winter or summer; they could only have been hybernatories, receptacles in which plants might be protected from wet or cold during winter, but from which they were transferred to the open air as soon as the spring became sufficiently mild. The substitution of glass-roofs, by increasing the quantity of light, put it at once in the power of the gardener to cultivate permanently in his greenhouse those natives of hot countries which are not capable of bearing the open air of Europe even during the summer. From the time of Switzer to the present day there has been a gradual improvement in the construction of greenhouses, the object being to supply the plants with as nearly the same amount of light when under the glass-roof, as they would have had if in the open air. The modern invention of curvilinear iron-roofs has accomplished this end in a most remarkable degree; for they substitute an obstruction to light amounting to only $\frac{1}{18}$ or $\frac{1}{17}$ for a loss equivalent to $\frac{1}{4}$ or even $\frac{1}{3}$.

The mode of heating such houses has given the modern cultivator additional advantages of the greatest importance. Stoves of all kinds not only dry up the moisture of the atmosphere, but impregnate the air with gaseous exhalations unfavourable to vegetation. The substitution of flues, while it equalised the heat, was still worse than the stove in drying and deteriorating the air; the introduction of fermenting vegetable matter, such as tan in a pit, in the interior of the house, remedied this evil in some measure, but the application of steam-pipes or hot-water pipes has had the great advantage of obviating every inconvenience, and has given the gardener the power of modifying the heat and moisture of his greenhouse at pleasure. Add to this, the rapidity of communication between one country and another, the long peace with which Europe was blessed, and the leisure it gave men to occupy themselves with domestic enjoyments, the great encouragement given to gardeners, the establishment of Horticultural Societies for the promotion of the art of gardening, and the discoveries made in vegetable physiology—add all these things to the improvements in greenhouses, under which name is here included all descriptions of glass buildings for horticultural purposes, and there is no difficulty in accounting for the present flourishing condition of European gardens.

There is one point further that requires to be noticed, as contributing to this result, and that is, the extension of the education of the working gardener. Great numbers of gardeners are now well informed in the higher branches of their profession. Instead of trusting to certain empirical rules, or to *receipts* for gardening operations, as if growing a plant was much the same thing as making a pudding, they make themselves acquainted with the principles upon which their operations are conducted; they acquire a knowledge of botany and vegetable physiology, and some even of physical geography, and thus they place themselves in the only position from which they can securely advance to the improvement of their art. The necessity of these subjects forming a part of all gardeners' education cannot be too strongly insisted upon; the Horticultural Society of London have recognised their importance by requiring all the young men in their garden to pass an examination in such subjects, in addition to their possessing the usual gardeners' acquirements; and although people ignorant of such subjects themselves have been found absurd enough to blame the proceeding, there can be no doubt that the world will give the Society the credit they deserve for having been the first to set this most important example, which we trust will be followed by all such institutions through the country.

In noticing modern gardens we must necessarily confine ourselves to a few of the most remarkable, passing by entirely those of private individuals, and in general all second-rate public establishments. The reader who is desirous of procuring detailed information upon the subject will find an ample account of all the best modern gardens in Mr. Loudon's excellent 'Encyclopedia of Gardening,' to which we have been much indebted for this article.

Although the restoration of gardens took place among the nobles of Italy, and many noble instances of wealth and taste applied to such purposes still remain, yet the political condition of that country is unfavourable to horticultural pursuits, and although there are gardens attached to most of the Italian cities, there are none of much note, except for their picturesque features and fine architectural embellishments. Those of Naples, Florence, and Monza near Milan, are among the most remarkable.

The Dutch, although too much attached to the stiff formal style of clipped hedges, straight walks, and architectural puerilities, have always had a great reputation as gardeners. Their wealth and their commerce with the Cape of Good Hope and the East Indies gave them for a while extraordinary advantages over other nations, and for a long time their garden of Leyden was considered the richest in Europe. It was begun in 1577; in 1633 it contained 1104 species, and was so rapidly enriched by the zeal of the wealthy Dutch merchants, that in 1720 no fewer than 6000 species were catalogued by Boerhaave, who was then professor of botany at Leyden. From this source was at one time obtained the principal part of the succulent and other plants native of the Cape of Good Hope. It was afterwards a good deal neglected, but was renovated under the care of Dr. Blume, and now ranks again among the finest of the public gardens of Europe.

In the Netherlands there are small public gardens, both at Antwerp and Ghent, and one of the finest in Europe at Brussels. Some years since it was a wretched place, scarcely deserving the name of a garden; but in 1826 it was removed to its present site on the boulevards, and entirely re-formed. It now contains extensive ranges of hothouses, and a large collection of plants. The roof of the houses is formed of curvilinear iron bars, and the whole is heated by steam. The principal range is seated on a terrace, with several fountains and broad flights of steps in front of it; while on a lower level are low ranges of pits for pine-apple plants and small tropical species.

Among the German sovereigns a taste for gardening has grown up in a degree unknown in any other country except among the English. A love of the beautiful, a fondness for natural objects, a quiet contented character, so characteristic of the German nations, has no doubt been the cause of this. In Loudon's 'History of Gardening,' no fewer than ninety closely printed pages are occupied with short accounts of the principal gardens of Germany only. Of these we can only select those of Munich, Berlin, and Vienna.

The garden of Munich is extremely rich in plants that can be cultivated in greenhouses and hothouses, but poor in those species which require to be grown in the open air: this happens in consequence of the severity of the winter, which destroys even the holly. There is a very fine range of hothouses, containing numerous palms, succulent and other plants. It is however considered that the plants, especially the Brazilian plants, in the hothouses at Nymphenburg are much finer than those at Munich.

The botanic garden at Berlin has long been one of the great sources from which the gardens of Europe have derived supplies of new plants, chiefly from Brazil, Mexico, and the Cape of Good Hope, in which country the king of Prussia has maintained collectors. It contains many hothouses and greenhouses, each of which is often dedicated to the reception of plants of some one tribe only. There is one for endogenous plants exclusively, another for ferns and palms, a third for Australian plants, and others for heaths, Cape, and Mexican plants; there are some very fine palms, and in all respects the collection of species is one of the most extensive in the world.

If the garden of Schönbrunn is less rich in plants than that of Berlin, it much excels it in the magnificence of its hothouses and greenhouses. The emperors of Austria have for above a century been anxious to render this garden the finest in the world; and no cost has been spared in sending gardeners to foreign countries in order to increase the collection. It is however chiefly by supplies from the tropical parts of America that this garden has been enriched. There are several ranges of glasshouses, in which the species are grouped with great taste, and which from their size allow the plants to grow with all their native tropical luxuriance.

Rivalling these imperial structures are the gardens of St. Petersburg, founded by the emperor Alexander on the Apothecaries' Island in the Neva. In a country with such a climate as Russia gardening can hardly exist, except with artificial heat under glass roofs, and it is necessary to call in aid all the resources of art in order to overcome the difficulties of nature. It is not surprising then that in this situation the glasshouses should exceed in extent those of all other parts of Europe. In the open ground there is a large collection of hardy plants, a quarter devoted to systematical botany for the purposes of students, an arboretum, and a division for medicinal species. One excellent feature in the internal arrangements of this garden is the placing the plants geographically, so that the most careless observer in proceeding through the different suites cannot fail to be struck with the changes in vegetation as he passes from Africa to America, to Australia, to India, China, and so on.

In France gardening has never been in a very flourishing condition; it is true that great quantities of vegetables are raised for the market, that the fruits of France are justly celebrated for their excellence, and the flower-markets of Paris are well supplied; it is also true that numerous excellent works on gardening have been written in France. But for the quality of their fruit the French are chiefly indebted to their climate, for the abundant supply of the vegetable market to their peculiar cookery, and for the excellence of their written works rather to the ingenuity of a few clever men, than to the general habits of the community. In flowers their taste is rather that of the Romans than of other European nations, for they are contented with a few showy kinds of sweet-smelling flowers, especially roses. Their great public gardens rather resemble in character those of the days of Henry VIII., than of the 19th century. There no doubt are exceptions to this statement, but the Jardin des Plantes at Paris, which is the largest of the public establishments in France to which the name of garden properly applies, is scarcely one. For a considerable period it consisted merely of various departments, in the open air, devoted to purposes of teaching; of an indifferent collection of hardy herbaceous plants, and hardy trees and shrubs; and of some contrivances to aid the student of agriculture. Of late years large glass-houses have been built, and many improvements made, yet even now there are few judges of gardens who would assign the Jardin des Plantes a place among the first class of European gardens.

In Great Britain it has not been the policy of the government to offer direct encouragement to either science or art, except in a sparing manner, but rather to throw the duty of fostering them upon the people. So far as gardening is concerned the government has been right; for if in this country such public gardens as we have enumerated are unknown, on the other hand no part of the Continent possesses such multitudes of good private gardens as Great

Britain. That which in other countries is a luxury, provided for at the public expense, is here rendered a kind of necessity, which all persons, from the cottager to the noble, strive to possess. Nothing can be more beneficial to the community, or more advantageous to horticulture itself, than this difference, for the result is not here and there a magnificent garden, and all around it comparative sterility, but a universal garden all over the country. The chief English garden containing a large collection of plants is that of Kew, which is certainly the richest in the world in Australian, New Zealand, and Himalayan plants, and which was, during the war following the first French revolution, almost the only place in Europe to which exotic plants were introduced in considerable quantity. In consequence of this establishment having had a monopoly of government support for above fifty years, it has been the channel through which an enormous quantity of new plants have been introduced to Europe from all parts of the world. For many years however it was unworthy of the nation, from the illiberal manner in which it was conducted. Of late years this system has been abandoned, a liberal management has been introduced, the collection is at least as accessible as that of other nations, and under the enlightened direction of Sir W. J. Hooker, the whole establishment has assumed such a magnitude and importance as to place it far above all other institutions of the kind. It now embraces within the botanic garden proper an area of seventy-five acres; has a noble palm house, 362 feet long, and in the centre 100 feet wide, and 66 feet high; several good hothouses; a new museum, &c.

Next in importance among public gardens was that of the Horticultural Society, at Chiswick, near London. It had been established at the expense of the members of the society, and was intended both as a place of experimental researches in horticultural science, and as a station whence the most valuable, useful, and ornamental plants of all kinds, might be distributed through the country; for which purposes its extent, amounting to 33 acres, was expected to be amply sufficient. For more than 30 years it exercised a most important influence over the progress of horticulture, and was the medium of introducing by far the greater part of the valuable exotics which have found their way into cultivation since its foundation. No association of individuals ever produced so marked an effect upon gardening in a few years as was brought about by the enormous distributions of cuttings of improved fruit-trees, of the finest kinds of vegetable seeds, and of new plants mostly imported direct from the British colonies and from the west coast of America, made annually from this garden, independently of the collections sent in return to all parts of the world. Of late years, however, it has been merely maintained as a place of experiment, and is about to be replaced by a new garden at Kensington Gore, at a cost of 100,000*l.*

A very successful establishment of a nearly similar kind is the Royal Society's Botanic Garden, which occupies the inner circle (an area of eighteen acres), in the Regent's Park. It has a very spacious conservatory, greenhouses, and an excellent collection of plants.

The botanic garden of Edinburgh is one of the finest and best-managed in Europe. It consists of 16 acres, delightfully situated, and includes everything that can be required for the purposes of teaching. The houses are remarkably good, and the healthy condition of the plants deserving of all praise. It is particularly celebrated for its beautiful specimens of heaths. Besides these, there are botanic gardens at Dublin, Glasgow, Liverpool, Cambridge, and Oxford; fine public gardens in Sheffield, Manchester, Birmingham, and some other large towns; and a garden at Chelsea, belonging to the Apothecaries' Company, who maintain it for the use of the medical students of the London schools. The Chelsea garden was once among the most celebrated in Europe, having been for nearly fifty years under the management of Philip Miller, the author of the 'Gardeners' Dictionary,' and whom Linnæus called the "prince of gardeners." Its situation has however become unfavourable for a garden, in consequence of the number of houses with which it is surrounded.

The number of species included in Loudon's 'Hortus Britannicus,' or catalogue of the plants either cultivated in Great Britain or indigenous, amounted in 1830 to upwards of 25,000, exclusive of Cryptogamous plants; and although a vast number of deductions must be made, it is not improbable that there are at this time nearly as many species known in the different British collections.

GARDEN HUSBANDRY is a branch of horticulture, the object of which is to raise fruits, vegetables, and seeds for profit on a smaller extent of ground than is usually occupied for the purpose of agriculture.

The best examples of this kind of industry are found among the market-gardeners near populous towns, particularly London, Paris, and Amsterdam. By the application of much manual labour and an abundant supply of manure they accelerate the growth of vegetables, and produce them more abundantly than where manure is not so easily obtained, or where there is not so large a demand for the produce.

The gardeners near Paris, some of whom have gardens within the outer walls of the city, are called *Maraichers*, from the situation of their gardens in a low district which was formerly a marsh (*marais*). The industry of this laborious class is proverbial. Their whole life is devoted to their gardens. They work the whole day in the greatest heat of the sun, and long before the rest of the inhabitants awake they are on their way to the market with their produce. The soil in which they raise their vegetables is naturally a poor sand, but by constant manuring it has been converted into a very rich mould abounding in humus. From its porous nature, and the frequent recurrence of dry summers, it would produce little without constant and abundant watering. The raising of water from numerous wells dispersed through the grounds, and conveying it to the growing plants, is the most laborious part of the work: during the whole summer this labour is incessant. There are large stone cisterns in which the water is allowed to remain, that it may acquire the temperature of the air; and from these it is carried by pipes into various channels which intersect the garden in every direction. These gardeners divide the season into three periods. The first begins in October, when they sow lettuces in a hot-bed, which are pricked out a month after, and planted finally in a sheltered border about the end of January, the ground having been well dug and abundantly manured with very rotten dung taken from the hotbeds. At the same time they sow radishes and leeks among the lettuces. The radishes are sold by the end of March, the lettuces in May, and the leeks in June. This completes the first season. The ground is now dug again, and manured with fresh long stable dung mixed with the earth of which the hotbeds were formed; in this they plant alternate rows of endive or scarolles (both varieties of chicory), and of cucumbers, which produce gherkins for pickling and sauces. The endive is sold in July, and the small cucumbers continue to be gathered till September. In the third season, which is the shortest, another digging and dunging is given, after which they sow radishes and small winter-salad, of which the French have a great variety. Winter endive is also planted for blanching. From this statement it appears that the ground produces a constant succession of culinary vegetables, and that it is manured thrice in the year. The great object is to have a rapid succession, and to allow no plant to occupy the ground long. Cabbages, cauliflowers, asparagus, artichokes, and other vegetables which remain a long time on the ground, are cultivated at a greater distance from Paris, where the land lets at a lower rate. These plants will bear to be carried to a greater distance than the delicate vegetables which are used chiefly in a raw state as salads. The only perennial plant in the gardens of the Maraichers is sorrel, of which there is a great consumption. This is continually dunged and watered to accelerate its growth, and is cut many times in the season. It must however be allowed that this forcing with manure and water, although it produces large and delicate fibres, does not give the flavour which belongs to vegetables grown in common earth, and which have had a more natural growth.

The market-gardens near London are on a larger scale, and if they produce fewer salads and pot-herbs, they produce better and more substantial vegetables, and likewise a large quantity of fruit. The best soil is a moist alluvial loam deposited from repeated overflowings of the Thames, which are now prevented by banks or dykes. But an increased demand for vegetables has caused much inferior soils to be cultivated as gardens, and increased labour and manure have supplied the deficiency in natural fertility. The gardeners' year properly begins in autumn, when the land is dug, or rather trenched, and well manured. Various vegetables, which will be required in winter, are now sown, and especially those which are to produce plants to be set out in spring; spinach, onions, radishes, and winter salads are sown, and when the weather is severe, are protected by a slight covering of straw or mats. In February, the cauliflowers which have been raised in frames or under hand-glasses are planted out. The cabbage plants are pricked out. The radishes, onions, and salads go to market as soon as they are of sufficient size, and sugar-loaf cabbages succeed them. As the cauliflowers are taken off, they are succeeded by endive and celery, and the same is the case with the cabbages. Thus there is a constant succession of vegetables, without one moment's respite to the ground, which, in consequence of continual stirring and manuring maintains its productive power. Deep trenching in some degree prevents that peculiar deterioration of the soil which would be the consequence of the frequent repetition of similar plants. This effect is most perceptible when the plants perfect their seed, which is seldom or never allowed to take place in market gardens; but great attention is paid to the species of plants which succeed each other on the same spot. The principle which experience and theory unite in establishing, is that of avoiding the too frequent recurrence of plants which belong to the same natural families. The great variety cultivated in gardens, in comparison with the common produce on a farm, enables this principle to be fully acted upon. Those gardeners who overlook this, and repeatedly sow or plant the same kind of vegetables in the same spots, are soon aware of their error by the diminution of the produce, both in quantity and quality, and by various diseases which attack the plants, however abundant may be the food supplied to them, or careful the tillage.

The principle on which the gardens are cultivated, is that of forcing vegetation by means of an abundant supply of dung, constant tillage, and occasional watering. The whole surface is converted into a species of hotbed; and crop succeeds crop with a rapidity which is truly astonishing. Those vegetables which arrive at a marketable state in the least time are always the most profitable, and those also for which there is a constant demand at all times of the year. With an abundant supply of manure, the market gardeners have no fear of exhausting the soil; and dissimilar vegetables may grow together on the same ground. Trees bearing fruit may be planted in rows, especially those of the dwarf kind; and under them those vegetables which do not require much sun may be raised to advantage. This is a very common arrangement in the market gardens near London. Raspberries, gooseberries, and currants, are planted in the rows between the trees. These rows being thirty or forty feet apart, leave ample room for vegetables. But in those gardens where the finest vegetables are raised, and particularly in those which are appropriated to the growth of seeds, no trees are permitted to shade the ground: even the hedges, if there are any, are kept low and clipped, that they may not give any shade, or harbour small birds. The market gardeners near London do not raise many peas or beans, except such as are forced and require glass frames to protect them. The chief supply of peas in the season comes from a greater distance, and is the produce of whole fields sown for that purpose by the farmers within a moderate distance of London. This crop would not be so profitable in a confined garden cultivated at a great expense.

The value of the produce in one year, from an acre of garden-ground in the most favourable situation, is almost incredible. The expenses of cultivation are very great. In inferior situations, where the produce is less, the expenses are also somewhat less.

A garden should always be laid out in a regular form, with narrow parallel beds, and paths between them. One or more roads, of sufficient width to allow a cart to pass, should intersect these beds at right angles, for the convenience of bringing manure and taking off the produce. The beds should not be above six feet wide; so that a person may easily pull up weeds, or gather the vegetables without treading upon the beds. The surface-soil taken from the paths serves to raise the beds, and in retentive soils may carry off the superfluous water after sudden and violent rains. The whole grounds should have been trenched two spits deep or more; and this trenching should be frequently repeated, to mix the upper with the under part of the soil, and distribute the decomposed dung throughout the whole depth. Thus in time a rich black mould will be produced, in which every kind of vegetable will grow most rapidly. For early plants, and those which are used in winter, and require to be protected from frost, narrow beds are made lying in a direction east and west, and sloping towards the south, with the north side raised high, so that their surface forms an angle of twenty or thirty degrees with the horizon. This gives the plants a protection from the north winds, and exposes them more to the influence of the sun. In very frosty weather, these beds are covered with mats or loose straw. We do not mention frames covered with glass, as they belong to a higher kind of horticulture: but a moderate hotbed made with fresh dung, and covered with mats laid over hoops, is indispensable for the raising of early vegetables. By these means radishes and various salads may be raised very early in the spring, and sometimes, in mild winters, without any interruption during the whole year.

An abundant supply of manure is indispensable in a market-garden, and this can generally be obtained in large towns at a trifling expense. The neighbourhood of a town is therefore a necessary circumstance towards the production of the crop, as well as its sale. It would be impossible to make a sufficient quantity of manure by means of the horses which are employed to carry the produce to market; and the extent of land usually laid out in garden-ground could not raise sufficient food for cattle, without taking up a space which may be more profitably employed. The only animal which can be kept to advantage by a gardener is a pig. This animal will live well on the offal of vegetables; and the gardens of cottagers could not well be kept in a fertile state if it were not for the manure made by the pigs.

The market-gardeners about Amsterdam are mostly Jews, and the vegetables which they bring to market are similar to those of the London or Paris gardeners; but they excel particularly in raising cauliflowers, large white cabbages for making *saur-kraut*, a dish much relished in the winter by the Dutch and Germans, [CABBAGE,] French beans, cucumbers and melons. They raise these last in such abundance, that heaps of them are sold in the markets at a very low rate. They also excel in the forcing of early peas and beans, and in the general management of hot beds.

The profits of a garden near London, of the extent of ten or twelve acres, are as great as that of a farm of ten times the extent cultivated in the best manner, without the help of purchased manure. But if manure can be obtained at a reasonable rate, as is often the case in great thoroughfares, where many horses are kept for public conveyances, although there be no immediate demand for vegetables, a garden may be very profitably cultivated, entirely for the purpose of raising seeds. This branch of industry is the more worthy of notice, as it may enable a cottager to improve his situation greatly by the produce of a small garden or allotment of land. The demand for seeds of all the most common productions of a garden, and especially of flowers, is great beyond belief, and the profit of those who retail them in small quantities is so great that they can afford a liberal price to those who raise them with proper care so as to keep the varieties distinct.

In some agricultural districts it is the custom for the labourers to plant turnips in their gardens in November, in order to obtain the seed in time for sowing in the next year. They choose the soundest and best shaped, and by attention in keeping the ground clean, and allowing only one sort to go to seed within a certain distance, they produce a better seed than the farmer could; because the labourer and his family having their garden constantly in view, can more easily keep off birds and watch the ripening of the seed, so as to allow it to come to perfect maturity, without danger of the pods bursting, and shedding the seed from being left too long. Thus they can collect a bushel or two of excellent seed from a small portion of land; and this, at the price of a guinea a bushel, which is cheaper to the farmer than if he raised it himself, or purchased it of the seedsman, is a very profitable crop to the labourer. An industrious cottager, without losing any time, with the help of his wife and children, may much increase his comforts in this manner, while at the same time he trains his children in habits of industry. To no class of men would a knowledge of garden husbandry be more useful. The improvement which may be made in the condition and character of the poor, by combining in their education a knowledge of the most common arts of life with that of letters, which is often the only thing taught in schools, must be evident to every man who has reflected on the subject; and of all these arts the most generally useful amongst an agricultural population is the art of horticulture. The cottager who is acquainted with the means of raising early garden produce, who can graft young trees, who knows what plants may be propagated with a little care, and be readily sold when in perfection, cam employ his labour with a double advantage. And many a man, from a very small beginning, has, with a moderate share of judgment and prudence raised himself to independence, if not to affluence; while he that plods on in the beaten track like a horse in a mill ends his days in ignorance and poverty.

The great superiority of those schools which have been established to teach the children of the poor to work as well as to read, over those which teach book knowledge only, is indisputable. A boy who can manage a little garden, who takes a pleasure in watching the seed he has sown, who plucks out every weed as soon as it appears, and who prides himself on the fruit and vegetables which he can place on his father's table, is more advanced in his education than he who can only read and write, however well he may do both.

Many plans have been proposed for the distribution of the crops in a cottage garden; but none of them are suited to every situation. Much depends on the nature of the soil, which may be better suited to one kind of produce than another; and also to the demand for any peculiar class of vegetables. New sorts may often be introduced with advantage. The raising of any useful plant with great care will often give a man a reputation, which makes it advantageous to him to confine himself to these principally, and raise them in the greatest perfection. An ingenious man will find out what is most for his own advantage; and from the list of plants which may be cultivated for ornament, or for use, a selection may be made which may be well suited to the situation of the ground and the circumstances of the grower. The practice of the market-gardeners may be examined with advantage; and long experience, with the test of profit, will lay down better practical rules than the most plausible theories.

An allotment of land, such as is now very frequently given to agricultural labourers, may be cultivated to great advantage by applying judiciously the general principles of garden husbandry. There are few cottages which have not already attached to them a small garden of a few perches, in which common vegetables, such as cabbages, onions, and early potatoes, are raised. The same vegetables may continue to be cultivated there, provided the situation is more convenient from its proximity to the cottage, or a small part of the allotment may be set apart every year for this purpose, so as to change the crops, which is always an advantage. But the remainder of the allotment should be cultivated on a regular plan, as a farm in miniature, with this difference, that all the operations should be performed with the minute attention of a gardener. Potatoes and wheat, if the soil is not too light for the latter, or rye, in very sandy soils, will be the principal crops, being immediately necessary to the support of the family. These crops have sometimes been recommended to be raised in every alternate year; but whatever be the tillage or manuring, there are few soils which will not soon be reduced in fertility by this constant succession. One-fourth of the land in wheat, and one-fourth in potatoes, is the utmost which can be profitably cultivated in one year. The remaining half of the allotment must produce pulse, roots, and green crops, by which animals may be fed and manure collected. An allotment of three acres will enable a cottager to keep a cow, by having a portion of it in clover or other artificial grass. In the 'Farmer's Magazine,' for February, 1802 (p. 38), there is an article drawn up by Mr. John Sinclair, in which it is shown how this may be effected without difficulty. But as the allotments usually given to labourers seldom exceed half an acre, or at the most an acre, the keeping of a cow is out of the question; and the only animal which can be profitably reared and fatted is the pig, to which we shall therefore confine our observations. By means of pigs, the cottager may greatly increase the profit which can be made from his allotment of land, keeping up at the same time a proper degree of fertility. One-half of his land must be cultivated to feed his pigs; besides the smaller potatoes which remain when the finest and best are taken out for the use of the family, he may give them beans, barley, carrots, parsnips, and turnips, especially the Roota Baga, or Swedish turnip; and all the straw must be used for litter. If this be strictly attended to, the greatest possible profit will be made from the land, without any danger of its being exhausted and losing its fertility. The rotations will therefore be—potatoes, with a great quantity of manure; then barley, then peas, beans, carrots, parsnips, and Swedish turnips, manured; and after these wheat. The application of the garden husbandry must be in the preparation of the soil by deep trenching and digging, carefully drilling or dibbling all the seeds in rows, stirring the soil between the growing plants, and keeping the ground clear of weeds by the hand and the hoe. These last are the most essential part of the cultivation, and are to be performed by the wife and children. By daily attention to the progress of the plants, and continual assistance at critical periods, sometimes thinning out, and at other times transplanting to produce an equal crop, and treating every plant as if it were a rare plant in a garden, the ground may be made to produce more than double what the most attentive farmer could expect on a larger scale. The additional labour, which is all light, costs the cottager nothing; but the farmer could not afford to pay for it at the usual rate of wages. If he could find hands to do it, he could not insure the minute attention which is naturally applied when the labourer is to receive all the advantage himself. The comfort which a well-managed allotment gives to a labourer with a numerous family is hardly credible by those who have not witnessed it; and if there were less profit, it would still be highly beneficial, in a moral and political point of view, that early habits of industry should be encouraged, and that the temptations which arise from want of employment should be taken away from the young by the useful and healthy occupations of the garden.

Let us add that on the garden culture of London neighbourhood, by which vegetables are raised for the metropolitan markets, the reader should consult Mr. Cuthill's paper on market-gardening in Morton's 'Cyclopædia of Agriculture.' And as to allotment culture; while anything which shall distract the cottager from his hired labour as the main source of his maintenance is bad, and while therefore large allotments of one acre or more are generally mischievous in their influence, there cannot be a doubt that, on a smaller scale, as Mr. Morton states in the 'Journal of the Royal Agricultural Society of England' the so-called allotment system is beneficial both to the labourer and his employer. If the possession of a store of field and garden produce be, as is alleged, a temptation to dishonesty, by the facilities which it affords for secreting the property of an employer, it is even more powerfully and in a variety of ways a security for good behaviour. The allotment of land which provides this store attaches a man to the locality in which he lives—it provides employment for those hours both of his children and himself which would otherwise be wasted—it adds to the comforts of his home—and it is generally a subject of common interest to himself, his neighbour, and his superiors. All these things tend to make him both contented and respectable. And if, as has been also said, the cultivation of an allotment does prove a tax upon the powers of the labouring man, incapacitating him in some degree by its need of extra work for those ten hours' labour which are due to his employer, it must be remembered, on the other hand, that, by every addition to the comforts and the means of home which it confers, his strength for those ten hours' labour is increased.

The following account of the way in which the allotment system was established at Whitfield, in Gloucestershire, and of its influence there, and the character of the population, is taken from Mr. Morton's paper already alluded to. The system there was not necessarily called for by excessive population; there was no special difficulty felt either by employers in providing labour, or by workmen in obtaining a livelihood; it was carried into operation as an addition to the comforts of an already tolerably satisfactory condition of the agricultural labourer.

The Whitfield allotments were first let many years ago, and, after twelve or fourteen years' cultivation, they are as fertile and productive as ever. Lying near the hamlet where most of the tenants live, the land is cultivated by them with the least possible waste of labour in passing to and fro, and with the greatest facilities both for the conveyance of manure to the land and the removal of produce from it. Most of the plots are 60 or 70 perches in extent, varying, however, from less than a quarter of an acre to rather more than half an acre. The way in which the land was let, and the whole scheme organised, may be very shortly described. On application to the late Earl of Ducie, an old pasture close to the village, about 11 acres in extent, was set apart for the purpose. Twenty or thirty cottages stand around or near the field, and to each a plot of ground was allotted. The field was, in the first place, divided into pieces varying in size between the extremes already named, according to the number of the cottagers and their ability to manage it. Paths were made between certain clusters of these plots, and a cart-way was left at either end of the land, for the removal of the produce. Such portions of the field as needed it were effectually under-drained. One-half of each plot was then dug up a good spit deep with the grafting-tool. All this was done during the winter. Sheep were turned in during the following summer. The grass of the halves left undug was thus eaten bare, and the halves of the several plots that had been dug were thus well trodden down. The allotments were apportioned at Michaelmas by lot, each cottager being told in what class, as to size, he was permitted to draw. To those of less ability than the others, whether owing to greater distance from the field, to having fewer children able to assist, or to want of strength or skill, the smaller plots were offered. To those of greater ability, whether of greater need or not, the larger plots were offered. It was urged that to allow these plots as a mere makeshift in aid of the necessitous, would have a pauperising tendency. It was an opportunity to them, offered according to their ability, not according to their need; and it thus acted as a premium upon every good quality they possessed or could acquire.

The previous management of the land placed it in the hands of these allotment tenants in first-rate order: the half which had been dug six months or more before, and trodden down all the summer by the sheep, was in the best possible condition for receiving wheat; and the other half in grass was ready to be at once dug up for potatoes, beans, or other vegetables, during the ensuing spring. The new rent demanded was determined by charging, in addition to the former agricultural rent, 5 per cent. upon all that had been expended by the landlord in carrying out the scheme. The drainage of the land, the plotting and digging it, the loss of rent of the land half dug,—all these added together, constituted a principal sum, on which 5 per cent. was charged in addition to the former rent. To this was added the estimated rates and taxes, and the cost of keeping fences in repair, together with 1*s.* from each of the allotments (about 3*s.* an acre on an average); this last to constitute a prize fund in furtherance of good cultivation. The whole rent thus ascertained was allotted over the several plots in proportion to their size and the quality of the soil.

The only conditions imposed upon the tenant, beyond the regular payment of his half-yearly rent, were that he should cultivate the land by manual labour, that he should not crop more than half his land with wheat or potatoes, and should give up the whole at the end of a year if required to do so.

There can be no doubt that this eleven acre field has been a great addition to the comforts of the village of Whitfield; and any one who sees the whole village population, young and old, at work upon it during those evening and even moonlit hours of spring and autumn, which would otherwise by many of them have been worse than wasted in the beer-house, must feel that the good influence of these field-gardens extends, beyond the mere material condition, to the character as well. The latter consideration is less capable of definite estimate or proof—it is incapable of reference with certainty to its causes; but in valuation of the former, there is no doubt that many a half-acre in the Whitfield allotment-field, which formerly contributed perhaps one-sixth to the annual keep of a cow, now provides one-fourth the bread-corn needed by a family, with more than that proportion of the potatoes they consume. Thirteen or fourteen bushels of wheat, and more than two tons of potatoes, are thus obtained from many a half-acre of land. "I would rather have my plot and pay a heavy rent for it, than have a *5l.*-note for nothing once a year," is the common testimony. The rent does not exceed *8l.* an acre, and the land was probably worth *50s.* as a pasture-field. It is punctually paid.

The Michaelmas rent-day was signalised by the award of prizes, namely, 1*l.* to the best cultivated allotment, and a return of the half-year's rent to the second best; and for this funds, as has been said, were provided by the allottees themselves, in the additional rent taken from them for this purpose.

The influence of the allotment system has perhaps been better shown at Silsoe (Bedfordshire) than in any other place. Mr. Trethewy, of that place, read a paper on it at a recent meeting of the London Farmers' Club, and he declared it as his opinion, the result of a large experience, that the subject involved the comfort and prosperity of the occupier quite as much as of the owner of the land or of the labourer. "Any system having a tendency to elevate the moral character of the labourer and improve his condition must be worthy of encouragement by the farmer." Mr. Trethewy alluded to the special fitness of this system where labourers live in villages, and where sufficient garden-ground cannot be obtained adjoining to the cottages. In choosing a field near the village, for the purpose of allotments, he says:—"The *nature* more than the *quality* of the soil should be considered, for it is astonishing how much poor thin land is improvable by spade husbandry, while strong and heavy clays are wholly unfit for the purpose of allotments, no matter how well they may be drained."

The following are his very sensible remarks on the importance of confining the allotments to a manageable extent of mere garden ground:—

"My experience convinces me that a rood is sufficient under almost any circumstances; and the greatest error that has been committed has been the allotting of too much land to one individual. To dwell upon the evils arising from such a proceeding is scarcely necessary, as it must be obvious that without sufficient capital the occupation of land cannot be attended with profitable results. Some instances in confirmation of this view have come under my own observation, and I can confidently assert that, instead of the position of such men having improved, it has retrograded. Occupied nearly the whole of their time upon their own land, they can no longer be classed under the head of labourers, and they actually injure regular workmen by throwing their labour into the market at seasons of the year when the demand for it is unusually depressed. If it be argued that the restriction of the system would have the effect of preventing a labourer from improving his condition, and effectually debar him from rising in the world by his own industry, I would answer that I am not now discussing the relative advantages of large and small farms, but am confining myself to the agricultural labourer in the broad acceptation of the term. Every employer knows, and every man of common sense must feel, that it is as important to the farmer to have his regular men at work at all times, as it is to the manufacturer or tradesman, and that the business of the farm could not be carried on without such regularity. I regard it, then, as a fatal error for the labourer to follow any pursuit that would at all interfere with the claim of his employer upon him; for, be it remembered, that it is upon *hired* labour that the working man must chiefly depend for his subsistence; and any scheme that has a tendency to interfere with this his chief capital, must very shortly end in disappointment and distress."

The following account of the Silsoe allotments is taken from Mr. Morton's paper in the 'Journal of the Royal Agricultural Society:' They date from the enactment of the new Poor Law, and the early promoters of the scheme were driven to it by the pressure of the poor's rates. The improvement in the condition of the labourer there and elsewhere is, no doubt, partly the effect of the new Poor Law, which has taught him that his first dependence must be on his own exertions; but a share in that improvement around Silsoe must certainly be allowed to the allotment system as there established. At first the allotment tenantry were allowed a considerable extent of land apiece—two acres or more. As much, indeed, as they declared their ability to manage was allotted to each applicant. But as these have gradually fallen in or failed, they have been subdivided; and from a rood to half an acre is now the ordinary extent allowed. There have been no restrictions placed upon the cultivators of these plots, but such as are also laid upon the farmers of the district. There is no formal provision against Sunday labour or against immorality, nor are there any special legal securities taken for the relapse of the land to the owner in case he should require it. Every security, nevertheless, exists as to all these particulars in the general sense of propriety which prevails, as well as in the knowledge that sufficient power exists in the management to enforce it. On riding round these allotments late in May, 1859, we saw poppies, turnip-seed, onions, peas, and cabbages, in some cases grown to a large extent; but the ordinary crops were wheat and potatoes for home consumption. In a few instances the land is in the hands of market-gardeners; but, as a general rule, the allotments are occupied by agricultural and other labourers; and the following table, extracted from Mr. Trethewy's paper, gives their extent and their number in the several parishes, together with interesting details regarding parochial rates since the period of their establishment:—

Parish.	Population per census of 1851.	Area of Parishes.	Number of Allotments.	Acreage of Allotment Land.	Annual Average of Five Years' Parochial Rates to Lady-day.					Parochial Rates for the Years							
					1858.			1848.		1828.		1833.		1835.		1838.	
		Acres.		Acres.	s.	d.		s.	d.	s.	d.	s.	d.	s.	d.	s.	d.
Silsoe	755	2067	78	24	2	10	in the £ upon rateable value.	2	3	7	5	5	6	3	3	2	6
Clophill	1186	2317	180	55	4	4		4	0	7	4	6	9	3	4	4	9
Flitton	656	1020	163	140	5	2		4	10	13	0	9	0	6	0	4	0
Pulloxhill	688	1584	131	51	3	2		3	6	11	0	12	0	6	0	3	8
Upper Gravenhurst	357	895	66	24	4	4		4	3	7	9	5	6	3	2	4	10
Lower Gravenhurst	58	757			2	0		2	1	2	0	2	0	1	0	2	10
			618	294													

We conclude with Mr. Trethewy's statement of the superiority of these clustered field-gardens over detached cottage-gardens, and of the advantages of encouraging rivalry by an annual judgment of cultivation and exhibition of produce:—

"(1) Every man has the advantage of the experience of the whole field, and generally benefits by it; whereas in a garden there are not those opportunities. (2) How frequently does one see a garden overrun with weeds, overgrown with trees, bushes, and fences, absolutely excluding sun and air, and producing next to nothing to the cultivator! In an open field-allotment the sun and air are freely admitted; the land is more easily kept clean, and the state of cultivation patent to all the neighbourhood. (3) I believe example has a strong influence in promoting good and clean cultivation among all classes of occupiers. With a view to encourage it amongst the allotment tenants of the district, a society, called the "Silsoe and Ampthill Labourers' Friend Society," was established about seventeen years ago. It offers several prizes annually for competition, and great interest is excited among the exhibitors. This society is under the patronage of Earl de Grey, and has Lord Wensleydale as president; while the stewards consist entirely of tenant-farmers, who thus evince their sense of its usefulness. The subscribers comprise the clergy and gentry of the neighbourhood, and the exhibition is invariably fully attended. In fact, all classes unite to promote the object it has in view; and the result is, an exhibition of fruits, vegetables, &c., that would surprise any one who had never before witnessed it. I believe this to be a most useful institution; and, where allotments prevail to any extent, I would strongly recommend the establishment of similar associations."

The almost universal testimony of experience on this subject confirms the conclusion to which, after Mr. Trethewy's paper, the discussion before the Central Farmers' Club led—that the system may always be expected to benefit both labourers and their employers, excepting under extravagant misguidance or neglect; that is, excepting (1) where the land set apart for the purpose is altogether unsuitable in character, or (2) too distant from the cottages of the allottees, or (3) where an excessive extent is permitted to the tenantry, or (4) an excessive rent demanded from them, or, lastly (5), where the tenantry are left entirely to themselves, and no effort made to excite their rivalry or pride in good cultivation.

GARGOYLE, GORGOL, or GURGOYLE, in Gothic architecture, a spout which is carried out from parapets in order to discharge the water from roofs clear of the wall. Mediæval architects, who almost invariably made the subsidiary features of their buildings of an ornamental character, so as to conduce to the general effect, saw at an early period the service which these humble objects might be made to render. Instead of having merely plain projecting pipes for their spouts, they covered the pipe with a block of stone, which they carved in general accordance with the rest of the sculpture; but, regardful of the ignoble purpose to which it was applied, gave it a decidedly grotesque character. Sometimes it is a human figure in a constrained attitude and with a distorted countenance; sometimes an animal or a monster. Usually the water is made to pass through the open mouth, but sometimes it passes from a pipe concealed below. Occasionally the figures appear to be caricatures of particular persons or bodies of men; occasionally they are gross; but almost always, as we have said, they are grotesque. They appear to have been first used in the Early English style; and they were most prominent in that and the Decorated.

GARLIC, a hardy perennial plant with bulbous roots, found growing wild in the island of Sicily, and in several other parts of the south of Europe. In gardens it is cultivated chiefly on account of its bulbs, which are much used in cookery, and occasionally in medicine.

It is the *Allium sativum* of botanists, and is regularly grown for the market. For this purpose, a light tolerably rich soil is selected in a dry warm situation. The ground should be well dunged for the crop which precedes garlic, and not when the garlic is planted; because, when this is done, the bulbs are very apt to canker, and to be infested with maggots.

It may either be planted in beds or in rows; if in beds, the distance between the plants may be seven or eight inches; if in rows (which is most recommended), they may be one foot apart, and six inches between the plants in the row. In gardens where the soil is light and dry, the best season for planting is late in autumn; but where the soil is wet, the operation should be deferred until spring, that is, to any time in February or March.

The plant is propagated by offsets, which it produces annually in considerable numbers, and which are commonly called cloves. The season of ripeness, which is generally in the end of July or August, is easily known by the leaves changing from green to yellow. At this period the bulbs should be taken up and spread out in the sun to dry, after which they may be tied in bunches and kept in a dry house for winter use, in the same way as onions.

GARLIC, OIL OF. When cloves of garlic [ALLIUM SATIVUM, in NAT. HIST. DIV.] are distilled with water in the manner described under ESSENTIAL OILS, 0·2 per cent of an oil is obtained of yellow colour, acrid taste, and strong disagreeable smell. After drying with chloride of calcium, and rectifying over potassium, it is obtained pure and colourless. It then constitutes the *sulphide of* the radical *allyl* (C_6H_5) [ORGANIC RADICALS] and has the formula (C_6H_5,S). The oxide of allyl, and a compound of allyl still richer in sulphur than the sulphide, appear also to be contained in the crude oil of garlic.

Sulphide of allyl is lighter than water, refracts light strongly, may be distilled without undergoing decomposition, is but slightly soluble in water, but very soluble in alcohol or ether. Sulphuric acid dissolves it without alteration, nitric acid converts it into oxalic and formic acids. On the addition of nitrate of silver to it, sulphide of silver is precipitated, and after a time crystals of double nitrate of silver and allyl are deposited. Sulphide of allyl also precipitates and forms double salts with the salts of gold, mercury, platinum, and palladium.

The mercury compound ($C_6H_5S,2HgS + C_6H_5Cl,2HgCl$) is decomposed on being distilled with sulphocyanide of potassium, sulphide of allyl being reproduced together with sulphocyanide of allyl (oil of mustard).

Other plants besides garlic contain sulphide of allyl; see ESSENTIAL OILS, *alliaria*, *cress*, *onion*, *radish*, &c.

GARNISHEE. [ATTACHMENT.]

GARTER, ORDER OF THE, one of the most ancient and illustrious of the military orders of knighthood in Europe, was founded by King Edward III. The precise year of its institution has been disputed, though all authorities agree that it was established at Windsor after the celebration of a tournament. Froissart says, Edward established the order on resolving to rebuild Windsor Castle, "which King Arthur had founded in time past," and fixed the first celebration of the order on "St. George's day next ensuing," that is April 23. 1344. Walsingham and Fabyan agree with this as the date of its foundation. Stow, who, according to Ashmole, is corroborated by the statutes of the Order, says 1350. Camden says it was founded after the battle of Crecy, at which Edward displayed his garter as a signal for the attack. The precise cause of the origin or formation of the Order is likewise not distinctly known. The common story respecting the fall of the Countess of Salisbury's garter at a ball, which was picked up by the king, and his retort to those who smiled at the action, *Honi soit qui mal y pense*, which afterwards became the motto of the order, is not entirely given up as fable. A tradition certainly obtained as far back as the time of Henry VI. that this Order received its origin from the fair sex. Ashmole's opinion was, that the Garter was selected at once as a symbol of union and a compliment to the ladies.

This Order was founded in honour of the Holy Trinity, the Virgin Mary, St. George, and St. Edward the Confessor. St. George, who had become the tutelary saint of England, was considered as its especial patron and protector. It was originally composed of twenty-five knights, and the sovereign (who nominates the other knights), twenty-six in all. This number received no alteration till the reign of George III., when it was directed that princes of the royal family and illustrious foreigners on whom the honour might be conferred should not be included. The number of these extra-knights was fifteen in 1860. The military knights of Windsor are also considered as an adjunct of the Order of the Garter.

The officers of the Order are a prelate, who is always the Bishop of Winchester; a chancellor, who till 1837 was the Bishop of Salisbury, but is now the Bishop of Oxford, in consequence of Berkshire, and of course Windsor, being transferred to that diocese; a registrar, who is the Dean of Windsor; garter principal king-at-arms of the Order; and a gentleman usher of the black rod. The chapter ought to meet every year on St. George's day, in St. George's chapel, Windsor, where the installations of the Order are held, and in which the banners of the several knights are suspended.

The original dress of the Knights of the Garter was a mantle, tunic, and capuchin or hood, of the fashion of the time, all of blue cloth; those of the knights companions differing only from the sovereign's by the tunic being lined with miniver instead of ermine. All the three garments were embroidered with garters of blue and gold, the mantle having one larger than all the rest on the left shoulder. The dress underwent various changes. Henry VIII. remodelled both it and the statutes of the Order, and gave the knights the collar, and the greater and lesser George, as at present worn. The last alteration in the dress took place in the reign of Charles II.: the principal parts of it consist of a mantle of dark blue velvet lined with white taffeta, and a surcoat of crimson velvet lined with white taffeta; a hood of crimson velvet; a cap or hat of black velvet lined with white taffeta, with an ostrich and heron plume; the stockings are of white silk, and the garter, which is of dark blue velvet, having the motto embroidered in gold letters, is worn under the left knee. The collar is of gold, of twenty-six pieces, each in the form of a garter, enamelled azure, appended to which is "the greater George," a figure of St. George encountering the dragon. The badge is a gold medallion representing St. George and the dragon, which is worn suspended over the left shoulder by a blue ribbon; hence it is a form of speech to say, when an individual has been appointed a knight of the garter, that he has received the blue ribbon. There is also a star of eight points argent, St. George's cross in the centre gules, encircled with the garter, worn on the left breast. The fashion of wearing the blue ribbon suspended from the left shoulder was adopted in the latter part of the reign of Charles II.

It is not generally known that, from the first institution of the Order of the Garter to at least as late as the reign of Edward IV., ladies were admitted to a participation in the honours of the fraternity. The queen, some of the knights-companions' wives, and other great ladies, had robes and hoods of the gift of the sovereign, the former garnished with little embroidered garters. The ensign of the garter was also delivered to them, and they were expressly termed *Dames de la fraternité de St. George*. The splendid appearance of Queen Philippa at the first grand feast of the Order is noticed by Froissart. Two monuments also are still existing which bear figures of ladies wearing the garter: the Duchess of Suffolk's, at Ewelme, in Oxfordshire, of the time of Henry VI., represents her wearing it on the wrist, in the manner of a bracelet; Lady Harcourt, at Stanton Harcourt, in Oxfordshire, of the time of Edward IV., wears the garter on her left arm above the elbow.

When Queen Anne attended the thanksgiving at St. Paul's in 1702, and again in 1704, she wore the garter set with diamonds, as sovereign of the Order, tied round her left arm.

GAS, a term originally employed by chemists as synonymous with air. It was first used in a very general sense by Van Helmont; but in consequence of the great number of permanently elastic fluids discovered by Priestley, so different in their properties from common air, and in order to avoid any confusion from the use of the same word to express both, Macquer employed the term gas, which has been universally adopted to distinguish from mere vapours all such elastic fluids as had not been rendered liquid or solid by reducing their temperature.

The experiments of Professor Faraday have however shown that elastic fluids which may be liquefied by reducing the temperature and increasing the pressure, are included in this definition. [GASES, LIQUEFACTION OF.] Still however there exists this difference between bodies in the elastic state:—vapours generated by the agency of artificial heat are reduced to solids or liquids when the heat is withdrawn; while gases preserve their aëriform state at common temperatures. It must however be admitted that the difference is one of degree only, and though not an essential one, it is usefully retained.

The number of gaseous bodies is great, and they possess in many respects such different properties, that it would be impossible to give a general description of them. The qualities therefore peculiar to each gas will be stated under its proper head; thus it will appear that some gases are elementary or simple in their nature, while by far the greater number are compound bodies; few of them exist in nature, but are mostly the products of chemical agency. Gases differ as to colour, odour, taste, specific gravity, and solubility in water; they vary also in their effects upon the animal economy, and in their relations to heat: most of them are either combustible or supporters of combustion, but one important gas at least belongs to neither class. Their powers of chemical combination are also extremely different; two gases only possess alkaline properties, whilst there are several gaseous acids.

One most important circumstance relative to gaseous bodies has been much discussed, and very opposite conclusions have been arrived at respecting it by philosophers of eminence; it is this, whether all gases, under the same volume and pressure, have the same specific heat. That this is the case, has been maintained by Haycraft, and Marcet and Delarive, and some others; while Dalton, Delaroche and Berard, Dulong and Dr. Apjohn, &c., are of opinion that equal volumes of different gases have not the same specific heat under similar circumstances.

It would be useless to detail the processes or to describe the apparatus by which chemists and physicists have arrived at such discordant results. The experiments of Delaroche and Berard, which are in general most relied upon, though complicated, were made with great care; they transmitted known quantities of gas, heated to 212° in a uniform current, through a calorimeter, the serpentine of which was surrounded with water, the temperature of which, as well as of the gas at its exit, being ascertained during the course of the process by very delicate thermometers. These chemists operated with a considerable quantity of gas, and used other precautions to avoid the errors into which other experimentalists had fallen.

The following is a statement of the results obtained by Delaroche and Berard, Dulong, and Apjohn, of the specific heats of equal volumes of the gases mentioned, under equal pressures:—

	Delaroche and Berard.	Dulong.	Apjohn.
Atmospheric air . . .	1·000	1·000	1·000
Nitrogen	1·000	1·000	1·048
Oxygen	·976	1·000	·808
Hydrogen	·903	1·300	1·459
Carbonic acid . . .	1·258	1.172	1·195
Carbonic oxide . . .	1·034	1·000	·996
Nitrous oxide . . .	1·350	1·159	1·193

Dr. Apjohn observes that the numbers which he has arrived at correspond tolerably well with those of Delaroche and Berard, except in the case of hydrogen; and he admits that he does not speak with much confidence of the numbers attached to nitrogen and oxygen.

There are some other properties which gases possess in common though they vary in degree. There is however one circumstance in which they all agree, whether they are elementary or compound, and whatever may be the difference of their specific gravity: they are subject to suffer the same increase of volume, when subjected to the same increase of temperature.

According to Dalton, when 100 volumes of air are heated from 32° to 212°, they become 132·5 volumes; by Gay-Lussac's experiments they increase to 137·5 volumes; by Crichton's to 137·48: the expansion therefore of each volume, according to Dalton is $\frac{1}{554}$, to Gay-Lussac $\frac{1}{480}$, and to Crichton $\frac{1}{480\cdot 25}$ for one degree of Fahrenheit's thermometer.

The discovery of this law has supplied chemists with a simple rule for determining what the known bulk of a gas at any temperature will be at any other temperature. Suppose, for example, it is desired to know what the bulk of 100 cubic inches of air at 32° will be at 60°;

subtract 32 from 480, the remainder is 448; to which add the degrees above zero indicating the temperature of the air, these are 32° and 60°, making 480 and 508. Then say 480 : 508 : : 100 : 105 · 832, the volume of the air at 60°.

It is well known that air suffers diminution of volume in proportion to the pressure to which it is subjected, and the same law holds good with all the more incondensible gases. In chemical analyses it is often requisite to make corrections for variations of barometric pressure, as well as of temperature in estimating the quantity of gaseous products. The following are the rules for this purpose, given by Professor Faraday in his work on chemical manipulation:—"A pressure of 30 inches of mercury, as observed by an accurate barometer, has been assumed as the *mean height* or *barometric pressure*, and volumes of gas observed at any other pressure frequently require to be corrected to what they would be at this point. For this purpose it is only necessary to compare the observed height with the mean height, or 30 inches, and increase or diminish the observed volume inversely in the same proportion. Thus, as the mean height of the barometer is to the observed height, so is the observed volume to the volume required. As an instance, suppose that 100 cubic inches of gas have been observed when the barometer stood at 30·7 inches: then, as 30 inches, or mean height, is to 30·7 inches, or observed height, so is 100, or the observed volume to a fourth proportional, obtained by multiplying the second and third terms, and dividing by the first: thus, $30{\cdot}7 \times 100 = 3070$, which divided by $30 = 102{\cdot}333$ cubic inches; this would be the volume of the gas at 30 inches of barometric pressure. Again, suppose a quantity of gas amounting to 20 cubic inches standing over mercury in a jar, the level of the metal within being 3 inches above that without, and the barometer at 29·4 inches. Then the column of 3 inches mercury within the jar, counterbalancing 3 inches of barometric pressure, instead of being 29·4, the latter is effectively only 26·4, and the correction will be, as 30 inches is to 26·4 inches, so is the 20 cubic inches observed to 17·6 cubic inches, the volume which the gas would really occupy if the mercury were level within and without the jar, and the barometer were 30 inches."

It is very commonly requisite to make corrections both for temperature and pressure in the same volume of gas, and it is of no consequence which is made first.

In chemical analyses various other considerations arise in ascertaining the quantities of gaseous products; as for example, the separation of or making the requisite allowances for the moisture which they contain: for these, as well as for the various modes of collecting, transferring, and preserving various gases, we must refer to the very excellent work just quoted.

The solubility of gases in water is extremely various. Dr. Henry thought that the volume of each gas absorbed by water is the same, whatever be the pressure to which the gas is previously subjected, but this has since been proved to be not strictly correct. If the weight of carbonic acid gas be doubled by subjecting it to the pressure of two atmospheres, water will still absorb its own volume of it. The following table exhibits the volumes of each gas absorbed by 100 volumes of water at 60° Fahr., and under a pressure of 30 inches of mercury:—

	Absorption in Volumes.	Authority.
Cyanogen	450	Gay-Lussac.
Sulphuretted hydrogen	366·6	Thomson.
Chlorine	200	Berthollet.
Carbonic acid	106	Cavendish.
Nitrous oxide	76	Saussure.
Olefiant gas	15·3	Saussure.
Phosphuretted hydrogen	5	Thomson.
Nitric oxide	3·7	Dalton.
Oxygen	3·7	Henry.
Carburetted hydrogen	3·7	Dalton.
Azote	2·5	Dalton.
Carbonic oxide	2·01	Henry.
Hydrogen	2	Dalton.

It may be observed, that in general the more easily a gas is condensable by cold and pressure, the more soluble it is in water: this will appear by comparing the above statements with that containing the pressure at which Faraday liquefied various gases. For more recent and accurate researches on the solubility of gases in water at different temperatures, see Bunsen's 'Gasometric Analysis,' translated by Dr. Roscoe.

A curious property of gases, and possessed by them in very different degrees, is that of their condensation by porous bodies, and especially by charcoal. [CARBON.]

A curious fact with respect to mixtures of gases was discovered by Dr. Priestley, which he thus states: "Different kinds of air that have no affinity do not, when mixed together, separate spontaneously, but continue diffused through each other." This he proved to be the case by several experiments; and more especially by one, in which he found that he was able to explode hydrogen and oxygen gases, which had long remained together, and which he justly argues must have been mixed, or he could not have fired them by an electric spark, in a vessel, the wires of which were at the top. He adduces this experiment to illustrate the fact that the gases which constitute the atmosphere do not separate according to their respective gravities, though they do not combine. (Priestley's 'Experiments, &c.,' vol. vi. p. 391.)

These experiments were repeated by Dr. Dalton, and he inferred from them that the particles of one gas, though repulsive to each other, do not repel those of a different kind; and that one gas acts as a vacuum with respect to another. If therefore a vessel full of carbonic acid be made to communicate with another of hydrogen, the particles of each gas insinuate themselves between the particles of each other till they are equally diffused through both vessels. This theory accounts not only for the mixture of gases, but for the equable diffusion of vapours through gases and through each other.

Another observation made by Dr. Priestley, and related with others of a similar kind ('American Phil. Trans.,' vol. v.), appears to have been entirely overlooked. He found that though a glass vessel was perfectly air-tight, yet if it had been broken, and the pieces joined with paint or cement, hydrogen gas contained in it would be changed for the external air. Döbereiner has since remarked the escape of hydrogen gas by a fissure or crack in glass receivers. Professor Graham, in an elaborate paper on this subject, has shown that gases diffuse into atmospheric air and into each other, with different degrees of ease and rapidity, the lighter ones escaping most readily, so much indeed, that hydrogen escapes five times more quickly than carbonic acid gas, which is about 22 times heavier. [DIFFUSION.]

To Dr. Priestley also we are indebted for the important discovery that gases can pass through membranes which are perfectly air-tight, and by this action he explained that of the atmosphere upon the blood in the lungs. In the memoir above alluded to he has also shown, that when a bladder containing hydrogen is put into a vessel of oxygen, or one with oxygen into a vessel of hydrogen, the bladder and the vessel of gas both contain both gases, owing to the passage of the gases from and into the bladder. It is also stated by Professor Graham, that if a bladder, half filled with air, with its mouth tied, be passed up into a large jar filled with carbonic acid gas, standing over water, the bladder, in the course of twenty-four hours, becomes greatly distended by the insinuation of the carbonic acid through its substance, and may even burst, while a very little air escapes outwards from the bladder. This however he does not consider as a case of simple diffusion; the result depends, first, upon carbonic acid being a gas easily liquefied by the water in the substance of the membrane, and therefore the carbonic acid penetrates the membrane as a liquid; secondly, this liquid is in the highest degree volatile, and therefore evaporates very readily from the inner surface of the bladder into the air confined in it. The air in the bladder comes to be expanded in the same manner as if ether or any other volatile fluid was admitted into it. Professor Graham further observes, that in the experiments of Dr. Mitchell and Faust and others, in which gases passed through a sheet of caoutchouc, it is to be supposed that the gases were always liquefied in that substance, and penetrates through it in a fluid form; and it is also to be noticed, that it is generally those gases which are more easily liquefied by cold or pressure that pass most readily through both caoutchouc and humid membranes.

Dr. Mitchell found that the time required for the passage of equal volumes of different gases through the same membrane was—

1	minute with	ammonia.
2½	minutes with	hydrosulphuric acid.
3½	,, ,,	cyanogen.
5½	,, ,,	carbonic acid.
6½	,, ,,	nitrous oxide.
27½	,, ,,	arseniuretted hydrogen.
28	,, ,,	olefiant gas.
37½	,, ,,	hydrogen.
113	,, ,,	oxygen.
160	,, ,,	carbonic oxide.
And a much longer time with		nitrogen.

In concluding we may observe that gaseous bodies are of the highest importance, as connected not merely with the well-being, but even with the existence of animals: two of them, oxygen and nitrogen, form our atmosphere; two of them, hydrogen and oxygen, constitute water; oxygen united with silicon and various metals forms the greater part of the crust of our globe; and chlorine is one of the elements of common salt.

GAS-LIGHTING, *Chemistry of.* The manufacture and consumption of gas for illuminating purposes is a process involving applications of chemistry at almost every step. There are, however, three distinct portions of the operation, the successful carrying out of which peculiarly require a knowledge of certain chemical principles: namely, 1st, the generation of gas: 2nd, its purification; and 3rd, its combustion for the production of light. We will, therefore, consider these points seriatim.

I. *Generation of Gas.*—The generation of nearly all kinds of gas for illuminating purposes is a process termed by chemists *destructive distillation*, and consists in placing coal, or other similar substance, in close vessels heated to a temperature varying from a red to a white heat. In practice, the vessels used are generally retorts, constructed either of cast iron or clay. The organic substances thus heated consist almost entirely of the elements carbon, hydrogen and oxygen, with small pro portions of nitrogen and sulphur. On exposure to the heat of the retorts, the hydrogen escapes partly in a free state and partly combined with the other elements, carbon, oxygen, nitrogen, and sulphur; the oxygen combines partly with hydrogen, forming aqueous vapour, and partly with carbon, producing carbonic oxide and carbonic acid gases; the nitrogen is evolved chiefly as ammonia, but partly also as cyanogen; the sulphur chiefly as sulphuretted hydrogen, but likewise as bisulphide of carbon; whilst a considerable proportion of the most fixed element, the carbon, remains in the retort as *coke*. Several of the gaseous or volatile compounds thus formed unite with each other to form secondary compounds. Thus, portions of the carbonic acid, sulphuretted hydrogen, and cyanogen, unite with ammonia to form respectively, carbonate of ammonia, sulphide of ammonium, and cyanide of ammonium. After leaving the retorts, these volatile and gaseous matters are cooled down nearly to atmospheric temperature, when nearly all the vaporous matters condense, forming a liquid consisting of two layers, a lower one called *tar* [COAL TAR], and an upper one containing chiefly the ammoniacal compounds above mentioned dissolved in water. [GAS LIQUOR.] The permanently gaseous product of the operation is called *crude* or *impure gas*, and generally contains the whole of the following ingredients:—

	Name.	Chemical Formula.
Illuminating constituents.	Olefiant gas	C_4H_4
	Other hydrocarbons	CnHn
	Benzole	$C_{12}H_6$
	Other hydrocarbons	CnH(n − 6)
Diluents	Light carburetted hydrogen	C_2H_4
	Hydrogen	H
	Carbonic oxide	CO
Impurities	Carbonic acid	CO_2
	Sulphuretted hydrogen	HS
	Aqueous vapour	HO
	Ammonia	NH_3
	Bisulphide of carbon	CS_2

The total quantity of these constituents, as well as the relative proportions in which several of them are generated, depends greatly upon the temperature at which the distillation is conducted. As a general rule, the lower the temperature the less gas is produced, but the greater is its illuminating effect when burnt. On the other hand, when a higher temperature is employed, a large volume of gas, but of inferior quality, is obtained.

Abstracting the impurities in the above list, it will be seen that gas contains two classes of constituents: namely—luminiferous constituents, or gases yielding light on combustion; and diluents, or non-luminiferous constituents, gases which practically yield no light on combustion. To the first class alone is the illuminating power of gas due; but one, at least, of the non-luminiferous gases is also necessary in order to enable the first class of constituents to burn without smoke and consequent loss of light. The members of the first class are all decomposed slowly at a red, and rapidly at a white, heat, depositing a large amount of carbon in the solid form, and being resolved into non-luminous gases. It is therefore obvious that, in the process of gas-making, more or less of these valuable constituents must be thus decomposed; the amount depending, on the one hand, upon the length of time during which they are exposed to a high temperature, and on the other, upon the number of the particles of such constituents which come into contact with the heated walls of the retort. Two methods for the prevention of this decomposition present themselves. The first consists in the rapid removal of the gases from the retort, and the second in the dilution of the luminiferous gases, whilst still in the retort, by the admixture or injection of non-luminous constituents. The first of these remedies has been extensively applied in the form of exhausters, which greatly facilitate the escape of the gases from the retorts, whilst both remedial measures have been secured in White's process of gas manufacture, in which a current of non-luminous gases is made to sweep through the retort, and thus rapidly remove the decomposable luminiferous constituents. This latter process, however, though undoubtedly based upon sound philosophical principles, has not come into extensive use, owing to certain mechanical difficulties in carrying it out.

The objects to be kept in view in the generation of gas for illuminating purposes are the following:—

1. The formation of a due proportion of illuminating and non-illuminating constituents; so that, on the one hand, the combustion of the gas shall be perfect, and without the production of smoke or unpleasant odour; and, on the other, the volume of gas required to produce a certain amount of light shall not be too great. For the production of an amount of light equal to that of twenty sperm candles of six to the pound, a consumption of gas greater than five cubic feet per hour ought not to be required.

2. The extraction of the largest possible amount of gaseous illuminating compounds from a given weight of materials.

3. The presence of the largest possible proportion of hydrogen amongst the non-illuminating constituents, to the exclusion of light carburetted hydrogen and carbonic oxide, so as to produce the least amount of heat and atmospheric deterioration in the apartments where the gas is consumed.

II. *Purification of Gas.*—A reference to the list of substances contained in crude or impure gas, given above, shows that there are five distinct compounds, all of which must be regarded as impurities. Of these, however, two—namely, bisulphide of carbon and aqueous vapour—may be left out of consideration, since the first, although highly objectionable in gas, as the cause of the sulphurous odour always perceived when gas is burnt in unventilated apartments, cannot be removed by any practicable process; whilst the second, which does little harm except diminish to some extent the illuminating power of the gas, cannot readily be abstracted, owing to the hydraulic nature of the apparatus used for the storage and measurement of gas. The processes used for the purification of gas are therefore restricted to the removal of sulphuretted hydrogen, carbonic acid, and ammonia. One hundred volumes of crude gas contain on an average the following quantities of these impurities:—

Carbonic acid	2·5
Sulphuretted hydrogen	·8
Ammonia	15

The two chie ingredients used for their removal, with more or less success, are hydrate of lime and hydrated peroxide of iron.

The first was formerly used suspended in water as milk of lime, through which the gas was made to bubble; but it is now almost universally employed in the solid pulverulent form. By direct chemical affinity, the hydrate of lime removes only sulphuretted hydrogen and carbonic acid from the impure gas; but the water which it contains enables it also to remove the greater part, at least, of the ammonia. The sulphuretted hydrogen forms, with hydrate of lime, water and a non-volatile sulphide of calcium, according to the following equation:—

$$\mathrm{CaOHO + HS = CaS + 2HO.}$$

Carbonic acid is rapidly absorbed by hydrate of lime, forming a basic carbonate, thus:—

$$\mathrm{2(CaO\ HO) + CO_2 = }\underbrace{\mathrm{CaO\ CO_2 + CaO\ HO}}_{\text{Basic carbonate of lime.}}\mathrm{ + HO.}$$

In both these reactions water is set at liberty, which assists in absorbing and retaining ammonia as mentioned above.

When hydrated peroxide of iron is used for the purification of gas, the carbonic acid is totally unacted upon, but the ammonia is perhaps more completely absorbed than by the lime process. The carbonic acid is either subsequently absorbed by slaked lime or, as is more frequently the case, it is suffered to remain in the gas, occasioning a considerable loss of light, but no additional nuisance to the consumer. The action of hydrate and peroxide of iron in removing sulphuretted hydrogen consists in the formation of sulphide of iron, water and free sulphur, thus:—

$$\mathrm{Fe_2O_3, 3HO + 3HS = 2FeS + S + 6HO.}$$

The cost of hydrated peroxide of iron would effectually prevent its use, if, like lime, it were only once available for the purpose; but the peculiarity and value of this oxide as a purifying agent consist in its capability of *revivification*;—that is, restoration to its original condition, or nearly so. This is effected by simple exposure to atmospheric air, the oxygen of which is so rapidly absorbed by the sulphide of iron as to occasion considerable risk of ignition unless the supply of air be moderate. Hydrated oxide of iron is regenerated, and the sulphur previously combined with the iron is set at liberty in the following manner:—

$$\mathrm{2FeS + 3O + 3HO = Fe_2O_3, 3HO + 2S.}$$

This alternate absorption of sulphuretted hydrogen and revivification might probably be carried on for an infinite number of times, were it not that the free sulphur ultimately accumulates to such an extent as to greatly reduce the efficiency of the mixture, and the sulphur therefore requires occasional removal either by distillation or roasting.

As it reaches the consumer, gas is very rarely contaminated with even a trace of sulphuretted hydrogen, but it frequently contains carbonic acid and invariably bisulphide of carbon, to which latter substance, giving as it does sulphurous acid on combustion, nearly all the annoyance experienced from the use of gas in dwelling-houses is due. In conclusion, sulphuretted hydrogen may be readily detected in gas by allowing a jet of the latter to blow upon a piece of white paper moistened with a solution of acetate of lead; the slightest discoloration of the paper shows the presence of sulphuretted hydrogen. Carbonic acid is best detected by allowing the gas to bubble through clear and transparent lime-water which will become turbid if the acid gas be present. Ammonia is recognised by allowing a jet of the gas to blow against paper tinted yellow with infusion of turmeric; ammonia changes the yellow of this paper to reddish brown. Bisulphide of carbon is detected by condensing the aqueous vapour formed by a gas flame: if the condensed product redden litmus paper this impurity is present.

III. *The combustion of gas.*—The production of artificial light depends upon the fact, that at certain high temperatures all matter becomes luminous. The higher the temperature the greater is the intensity of the light emitted. The heat required to render matter luminous in its three states of aggregation differs greatly. Thus, solids are sometimes luminous at comparatively low temperatures, as phosphorous and phosphoric acids. Usually, however, solids require a temperature of 600° or 700° Fahr., to render them luminous in the dark; and must be heated to 1000° Fahr. before their luminosity becomes visible in daylight. Liquids require about the same temperature. But to render gases luminous, they must be exposed to an immensely higher temperature; even the intense heat generated by the oxhydrogen blowpipe scarcely suffices to render the aqueous vapour produced visibly luminous, although solids, such as lime, emit light of the most dazzling splendour when they are heated in this flame. Hence, those gases and vapours only can illuminate, which produce or deposit solid or liquid matter during their combustion. This dependence of light upon the production of solid matter is strikingly seen in the case of phosphorus, which when burnt in chlorine produces a light scarcely visible; but, when consumed in the air or oxygen, emits light of intense brilliancy; in the former case, the *vapour* of chloride of phosphorus is produced, in the latter *solid* phosphoric acid.

Several gases and vapours possess this property of depositing solid matter during combustion, but a few of the combinations of carbon and hydrogen are the only ones capable of practical application: these latter compounds evolve during combustion, only the same products as those generated in the respiratory process of animals, namely, carbonic acid and water. The solid particles of carbon which they deposit in the interior of the flame, and which are the source of light, are entirely consumed on arriving at its outer boundary; their use as sources of *artificial light*, under proper regulations, is therefore quite compatible with the most stringent sanatory rules.

The light emitted during the combustion of coal gas is due entirely to the illuminating class of its constituents, which yield an amount of light proportional to the quantity of carbon contained in a given volume; thus, *propylene* and *butylene* yield respectively 50 and 100 per cent. more light than olefiant gas, because they contain respectively 50 and 100 per cent. more carbon in a given volume.

It would not be desirable to employ a gas containing only luminiferous ingredients, even if it were possible to manufacture such a gas, because it is exceedingly difficult to consume these constituents without the production of smoke attendant on imperfect combustion. An inflammable diluting material is therefore necessary to give the flame a sufficient volume, so as to separate the particles of carbon farther asunder, and thus diminish the risk of their imperfect combustion.

All the three diluents above mentioned perform this office equally well; but if we study their behaviour during combustion we shall find that in a sanatory point of view hydrogen is greatly to be preferred.

The two objections most frequently urged against the use of gas in apartments are, first, the heat which it communicates to the atmosphere; and, second, the deterioration of the air by the production of carbonic acid. Now, in their action upon the atmosphere in which they are consumed, the above three diluents present striking differences in these two respects.

One cubic foot of light carburetted hydrogen, at 60° Fahr., and 30 inches barometrical pressure, consumes two cubic feet of oxygen during its combustion, and generates one cubic foot of carbonic acid, yielding a quantity of heat capable of heating 5 lbs. 14 oz. of water from 32° to 212°; or causing a rise of temperature from 60° to 80·8° in a room containing 2500 cubic feet of air.

One cubic foot of carbonic oxide at the same temperature and pressure, consumes during combustion half a cubic foot of oxygen, generates one cubic foot of carbonic acid, and affords heat capable of raising the temperature of 1 lb. 14 oz. of water from 32° to 212°; or that of 2500 cubic feet of air from 60° to 66·6°.

One cubic foot of hydrogen at the same temperature and pressure, consumes half a cubic foot of oxygen, generates no carbonic acid, and yields heat capable of raising the temperature of 1 lb. 13 oz. of water from 32° to 212°; or that of 2500 cubic feet of air from 60° to 66·4°.

This comparison shows the great advantage which hydrogen possesses over the other diluents, especially over light carburetted hydrogen, which is evidently a very objectionable constituent, and shows that a normal gas for illuminating purposes should consist of illuminating hydrocarbons diluted with pure hydrogen.

As an illuminating agent gas is superior to all others in an economical point of view, as seen from the following table, showing the comparative cost of light from various sources equal to 20 sperm candles, each burning for 10 hours at the rate of 120 grains per hour:—

	s.	*d.*
Wax	7	2½
Spermaceti	6	8
Tallow	2	8
Sperm oil (Carcel's lamp)	1	10
London gas	0	4½
Manchester gas	0	3
Liverpool gas	0	2½

As regards the production of a minimum amount of carbonic acid and heat, gas is also greatly superior to other light-giving agents, as will be seen from the following comparison, showing the absolute amounts of carbonic acid and the relative quantities of heat generated per hour, by various sources of light each equal to 20 sperm candles burning at the rate of 120 grains per hour:—

	Carbonic Acid.	Heat.
Tallow	10·1 cubic feet.	100
Wax . . . . . Spermaceti . . .	8·3 ,,	82
Sperm oil (Carcel's lamp) . .	6·4 ,,	63
London gas	5·0 ,,	47
Manchester gas	4·0 ,,	32
Liverpool gas	3·0 ,,	22

Notwithstanding the great economy and convenience attending the use of gas, and in a sanatory point of view, the high position which, as an illuminating agent, coal gas of proper composition occupies, its use in dwelling-houses is still extensively objected to. The objections are partly well founded and partly groundless. As is evident from the foregoing table, even the worst London gases produce, for a given amount of light, less carbonic acid and heat than either lamps or candles; but then, where gas is used, the consumer is never satisfied with a light equal in brilliancy only to that of lamps or candles, and consequently, when three or four times the amount of light is produced from a gas of bad composition, the heat and atmospheric deterioration greatly exceed the corresponding effects produced by the other means of illumination: but by using a gas of high illuminating power, like those of Liverpool or Manchester, it is evident that two or three times the light may be employed with the production of no greater heat or atmospheric deterioration than that caused by wax candles, or the best constructed oil lamps.

But there is nevertheless a real objection to the employment of gas-light in apartments, founded upon the production of sulphurous acid during its combustion; this sulphurous acid is derived from bisulphide of carbon, which has already been referred to as incapable of removal from the gas by the present methods of purification.

This impurity, which is more or less encountered in all coal-gas now used, is the principal, if not the only, source of the unpleasant symptoms experienced by many sensitive persons in rooms lighted with gas. It is also owing to the sulphurous acid generated during the combustion of this impurity, that the use of gas is found to injure the binding of books, and impair or destroy the delicate colours of tapestry; therefore the production of gas free from this noxious sulphur compound is at the present moment a problem of the highest importance to the gas manufacturer, and one which demands his earnest attention.

As it is impossible for the consumer to procure gas free from this objectionable compound, the only method of obviating its unpleasant and noxious effects, is to remove entirely the products of combustion from the apartments in which the gas is consumed, and thus prevent them from mingling with the circumambient air. This suggestion was first made by Faraday, who accomplished this object by his very beautiful and effective ventilating burner. This apparatus, which is used at Buckingham Palace, Windsor Castle, the House of Peers, and in many public buildings, may be truly said to have brought gas illumination to perfection; for not only are all the products of combustion conveyed at once into the open air, but nearly the whole of the heat is in like manner prevented from communicating itself to the atmosphere of the room. The only obstacles to the universal adoption of this description of burner are its expense, and the difficulty of conveying the ventilating tube safely into the nearest flue without injuring the architectural appearance of the room. The public at large will therefore still await the removal of the objectionable compound in question, by the gas manufacturer, before they will universally adopt this otherwise delightful means of artificial illumination. For the method of analysing gas, and for the chemical mode of determining its illuminating power, see GASOMETRIC ANALYSIS, *Analysis of Coal Gas.*

GAS LIQUOR. In the manufacture of gas for illuminating purposes, by the destructive distillation of coal, certain liquid products are always obtained. Evolved from the heated coal in the state of vapour, they condense by the mere cooling of the gas, and then separate into two portions, the one having an oily character and constituting *coal-tar* [COAL-TAR]; the other being water containing some matters in solution, and known as *gas-liquor*, or the ammoniacal liquor of the gas-works.

The substances contained in this solution are ammoniacal gas, and the following compounds of ammonia with volatile acids:—

Carbonate of ammonia,
Sulphate of ammonia,
Sulphide of ammonium,
Chloride of ammonium,
Ferrocyanide of ammonium.

On account of the immense demand for ammoniacal salts by metallurgists, calico-printers, colour-makers, artificial manure manufacturers, and others, gas-liquor, although a secondary product in gas-manufacture, is of considerable commercial value. The various methods that a knowledge of chemistry would suggest for the extraction and working of the ammonia contained in gas-liquor have consequently formed the basis for much speculation, and many patents embodying those methods have been taken out. For some purposes it is sufficient to add hydrochloric or sulphuric acids to the crude gas-liquor, to well agitate the mixture, allow impurities to subside, concentrate to the crystallising point, and expose the crystals to a slightly elevated temperature. The resulting salt is still of course very impure, but serves for the preparation of carbonate of ammonia by sublimation with chalk; or certain portions of the impure chloride alone may be farther purified by sublimation. For purposes in which purer ammoniacal salts are desired, the ammonia is displaced from its combinations in gas-liquor by a stronger base, usually lime; it is separated from the resulting lime-salts and impurities by distillatory processes, and its vapour condensed in water containing the acids with which it is wished to unite it. From these solutions the salts are obtained by evaporation and crystallisation.

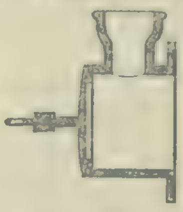
For a list of, and details concerning the various patented processes for "the manufacture of ammonia and ammoniacal salts from the ammoniacal waters of coal gas-works," see 'Pharmaceutical Journal,' vol. xiii., first series, pp. 63 and 113.

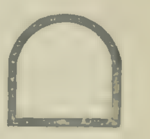
GAS, MANUFACTURE OF. There are few more remarkable illustrations of the occasional stagnation of human invention for long periods, and of its subsequent feverish activity, than may be discovered in the history of artificial lighting. It is true that from a passage in Ammianus Marcellinus, in which he speaks of the towns in the time of Constantius, A.D. 353, and says that it was easy for conspirators to carry on their treason in them, "ubi pernoctantium luminum claritudo dierum solet imitare fulgorem," it may be supposed that the ancients paid some attention to the lighting of their streets, but the most elaborate critical investigations, and the most careful observations upon the remains of antiquity, have failed to discover traces of any other system of lighting amongst the Greeks or Romans, than very rude oil lamps without chimnies, candles of very imperfect manufacture, torches, or open coal fires. The same methods of public and of private lighting were retained, without improvement, throughout the middle ages; nor was it indeed until about the end of the 17th century that anything like a regular system of public lighting was attempted in any of the capitals of Europe. The first decided steps towards the improvement of this important detail of domestic comfort and public security, seems to have been taken under the guidance of M. de Sartines; for under his protection Laugrin introduced the reflector lamps, which were subsequently improved by Quinquet; and finally Argand perfected the ordinary oil lamps, by the introduction of the cylindrical wick and chimney, with a double current of air. Letters patent for this invention were granted on 5th January, 1787, but they were abolished during the French revolution of 1793.

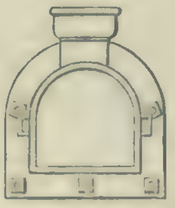
Whilst the methods of artificial lighting were thus slowly progressing in the beaten track, Mr. Murdoch was engaged in experiments on the combustion of coal gas; and in 1792 he lighted his house and offices at Redruth in Cornwall, by that means. In 1798, Murdoch also lighted the shops of Messrs. Bolton and Watt at Soho with "inflammable gas;" and in 1802 it appears that a M. Lebon proposed to light a portion of Paris in a similar manner. The Jesuits' College at Stonyhurst, was amongst the earliest public institutions to adopt the "new light;" and it was in the course of executing this work that Mr. Clegg introduced the method of purifying the gas by passing it through lime water; this took place about 1807. In the same year Mr. Winsor, who had taken a very conspicuous part in diffusing the knowledge of the new method of lighting, obtained permission to apply his apparatus to a few lamps in Pall Mall. The first act for the establishment of a gas company was passed in 1810, and under its powers the Chartered Gas Company commenced operations, in spite of the sneers of scientific men and the opposition of practical ones. It was not until the 31st of December, 1813, that gas lighting was employed on a large scale in streets, by the lighting of Westminster Bridge; and on April 1st, 1814, the parish of St. Margaret's Westminster substituted gas for oil throughout their district. About the beginning of the year 1820 Paris imitated the example thus set; and subsequently to that period almost every city of importance in England, and on the continent, has adopted the use of gas. The meter, for registering the consumption of gas, was invented in the year 1815 by Mr. Crosley, and since that period gas has been commonly applied in lighting private houses. It may convey some idea of the importance of the gas manufacture of London to state here that there are no less than nineteen companies established for this purpose, with a paid up capital of nearly six millions sterling.

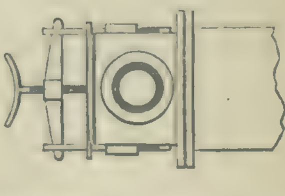
The manufacture of gas is conducted upon rather different principles in the large establishments of such a town as London, from those observed in the majority of small country works; and it will therefore be desirable to notice in detail the various processes of the manufacture, in order to explain some of the reasons for these particular variations. In so doing, the system to be observed is that of the ordinary course of manufacture; or to discuss, 1st, the carbonisation and distillation of the coal; 2nd, the condensation and purification; 3rd, the storage of the gas; 4th, the distribution, under the sub-divisions of the mains and of the fittings; and 5th, the accessory buildings, or processes employed. The conditions connected with the discharge of the public service by private companies, or by municipal bodies, will form the subject of a special article [PUBLIC LIGHTING], on account of the warm discussions which have lately taken place, and of the singular differences of system which prevail in the matter.

1. The distillation of the coal, or the process by means of which the illuminating gases are separated from the solid carbon of the coal, is effected in close vessels known by the name of *retorts*. These retorts are at the present day long, closed, horizontal vessels of cast iron, or of fire clay, or occasionally in large town-works they are built up with fire bricks; and, as might be expected, they are of every variety of form and cubical capacity. Generally speaking, however, retorts of cast iron are made of the shape of the letter D, and they are about 7 feet 6 inches long, by 20 inches wide, and 12 inches deep; their capacity being such as to allow them to carbonise 120 lbs of coal in each charge. The clay retorts are sometimes made of the same form and dimensions as the iron ones, but they are very frequently made perfectly cylindrical; or in large works they are made in lengths of about 16 inches, joined together with fire clay, so as, in fact, to form ovens about 7 feet long by 5 feet wide, and 18 inches high, as in some of Mr. Grafton's works; or, as in the case of the Phœnix Works, London, they are put together in three pieces, making retorts of 20 feet long, by 16 inches diameter. There are numerous descriptions of retort ovens formed of fire tiles and bricks now in use in the London gas factories, such as those for instance of the Westminster station of the Chartered Company, which are about 22 feet clear length, by about 20 inches wide, and 13 high, and are fed from both ends; or again in Paris, and at the London Gas Works, Vauxhall, a large oven is occasionally used, capable of carbonising as much as six tons of coals at a time, for the purpose of obtaining a description of coke adapted for foundry, or other analogous purposes, at the same time that the illuminating gases are secured.



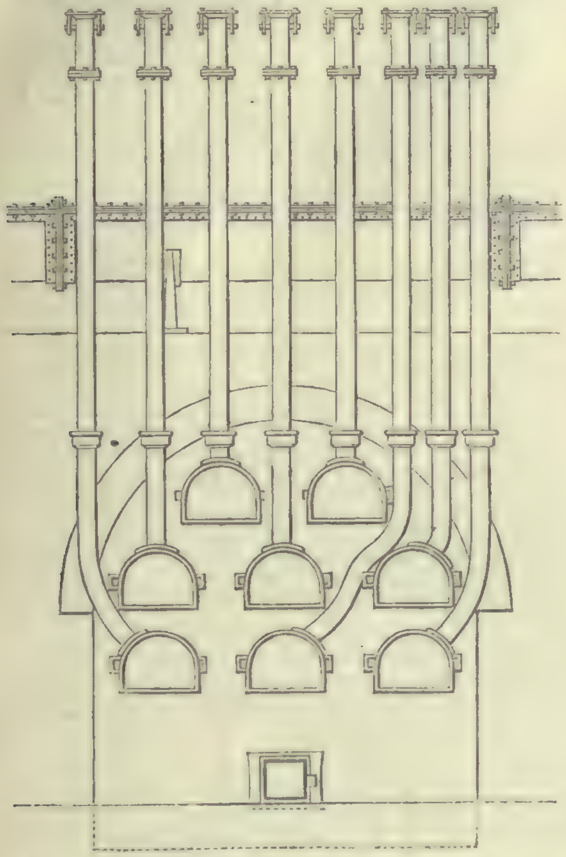






Now the differences we thus find to prevail in the shape, dimensions, and materials of gas retorts, extend likewise to the manner of their arrangement in the same bed, as the assemblage of retorts heated by one furnace is called. According to the size of the locality to be supplied, 1, 2, 3, 5, 7, or even as many as 12 retorts are fixed in the same setting, though it is very questionable whether any real advantage be gained by exceeding the number of 7 or 8. The advantage of placing several retorts in one bed, being only that they require, under such circumstances, less fuel to bring the coal to the required temperature, there must be a point at which the increased cost of labour, from the difficulty of *drawing* (or removing the carbonised coal from the upper retorts) must balance the economy of fuel. Assuming then that seven or eight retorts in a bed are the most convenient and economical arrangement in large works, the setting of the retorts in small works would be regulated on the calculation that each ordinary D retort will yield a fair working result of from 2500 to 2700 cubic feet per day: and the number of such retorts in a bed must be regulated according to the size of the town and its consumption of gas, so as to have the smallest possible number of furnaces alight at the same time. The nature of the fuel burnt under the retorts may modify the ordinary course of proceedings, however, and in some cases the character of the foundations upon which the retort beds are placed may render it unadvisable to concentrate a great weight in one spot.

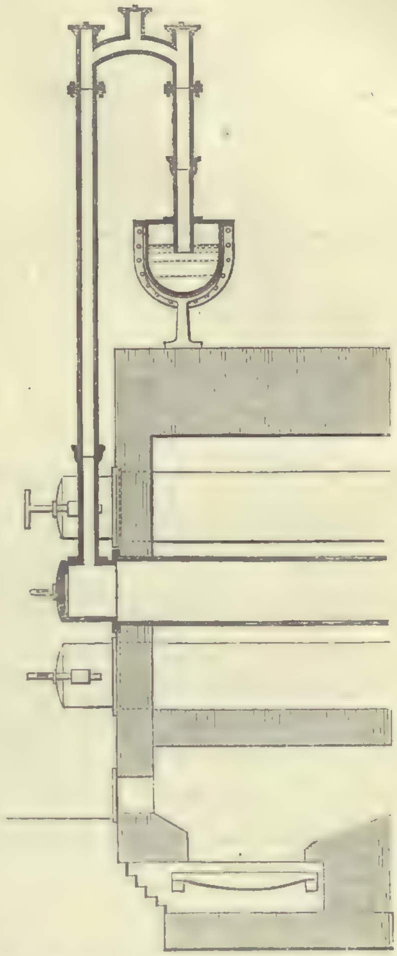
Whatever be the shape of the ordinary retorts (that is to say, of those in which no attempt is made to obtain metallurgic coke), the exposed end of the retort bears a *mouthpiece*, to which is attached the *rising* or *stand-pipe*, or the pipe through which the crude gas passes from the interior of the retort into the *hydraulic main*, to be described hereafter. As this mouthpiece is frequently exposed to severe shocks, it is made of cast iron, even when clay retorts are used; and it bears two ears which receive the ends of the *lids*, or covering-plates, and the *cross-bars* used for fastening the lid (by means of a strong square threaded screw) to the mouthpiece. The imperviousness of the junction of the mouthpieces and lids is, moreover, assisted by covering the bearing surface with a luting composed of the spent lime from the purifiers (when that material is used) mixed with fire-clay. The stand-pipe is usually formed in a separate casting from the mouthpiece, and



it is bolted on to a species of saddle formed to receive it; the diameter at the bottom, in ordinary retorts, being generally about 6 inches, and at the top 4 inches. In such cases the length of the stand-pipe is about 10 feet; but the number of retorts in a bed must naturally affect this dimension. At the top of it there is fitted one end of a short bent pipe, known as the *H-pipe*, or the *bridge-piece*, which by its other end is connected with the *descending pipe*, and by it with the hydraulic main; the lower end of the descending pipe being carried about two or three inches below the surface of the water and tar of the main, and thus converted into a species of hydraulic seal, to prevent the return of the gas to the retort after it has once risen through the water. The H-pipes bear at the top a moveable cup.

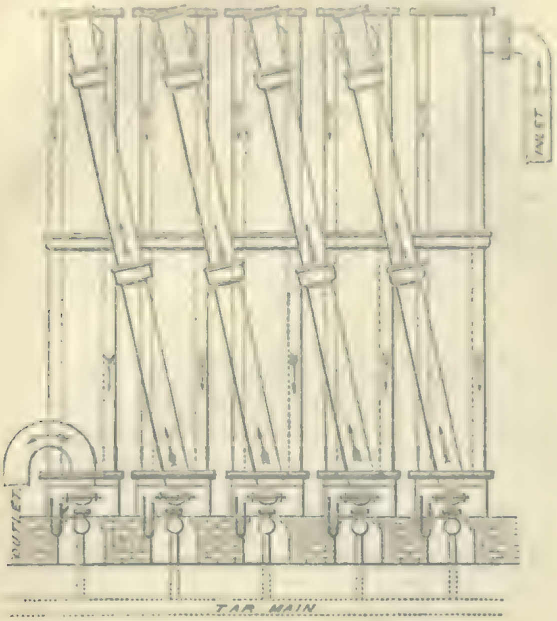
The hydraulic main is a species of iron trough, rather more than half filled with water, which is sometimes carried on columns in front of the mouthpieces of the retorts, but is, generally speaking, placed a little within the line of the retort setting, so as to allow of its being supported from the same. Whether the hydraulic main be within or without the front line of the retort beds, it must run from one end of the retort house to the other; and under any circumstances it must be kept sufficiently high to allow good head-room beneath it, and to remove it from the direct action of the flames which escape when the retorts are being charged. The dimensions of the main must be sufficient to contain the quantity of tar and water which should be able to close the immersed ends of the H-pieces when the mouthpieces of the retorts are opened; for at that period the pressure of the gas into the main will cause the tar to rise in the pipe to a point depending upon the pressure itself. Another condition to be observed in the construction of an hydraulic main is, that the exit pipe should be placed above the surface of the tar, in order to prevent any interference with the passage of the gas to the condensers. A small outlet pipe is inserted at the ends of the main, through which the surplus tar flows into the tar cistern; the lower end of this overflow pipe must be carefully sealed, in order to avoid any escape of gas through it.

It would perhaps be dangerous in a general description of the process of gas-making, to attempt to lay down the laws for the construction and dimensions of the furnaces and flues required for the purpose of heating the retorts to the requisite temperature for the distillation of the coal; because the varieties in the dimensions of the retorts and of the materials employed in their construction, as well as of the fuel used for heating the retorts, render it necessary to introduce many modifications in the furnaces. The object to be attained is, to heat cast-iron retorts to a uniform cherry-red heat, in the interior; or to heat clay retorts to a white heat, with the smallest possible expenditure of fuel; and, after all, much must be left in these matters to the tact and skill of the operative engineer who fixes the work. It is usual, it may be here added, to calculate that, when retorts are heated by the waste coke of the gas factory itself, about from 25 to 35 per cent. of the coke made is burnt under the retorts. Sometimes tar is burnt in the furnaces; but as the local markets for the residual products of gas-making constantly vary, it is not advisable to attempt to discover any general law in respect of the nature of the fuel, any more than it was in the case of the size and details of the furnaces and flues. The mode of charging the retorts is another detail of the service of a retort house in which many differences prevail; for in small country works, where it is important to keep down the outlay for labour, the stoker is made to charge the retorts by means of a shovel; whereas, in large works, the whole of the charge is frequently placed in a *scoop*, and is inserted in the retort at once: the object to be attained in either case being to distribute the coal for distillation in a uniform coat of about 5 inches in thickness all over the bottom of the retort, and to leave the mouth open for the shortest possible time, in order to avoid any unnecessary lowering of the temperature. There are, in fact, few details in the process of gas-making of equal importance to the regulation of the temperature of the retorts, and it is impossible to call the attention of the workmen too forcibly to the subject. If, for instance, the heat be maintained for any length of time at a very high point, the retorts will be burnt out rapidly, and the proper quantity of gas per ton of coal will not be obtained. If, on the other hand, the heat of the retorts be too low, a large quantity of tar will be formed, the quality of the gas will be inferior, and the rate of distillation will be protracted. When the temperature of the retorts is properly regulated, and the quality of the coals used is of an ordinarily good description, it may generally be calculated that a ton of coals will yield between 8700 to 9300 cubic feet, measured by the station-meter before being passed into the gas-holder.



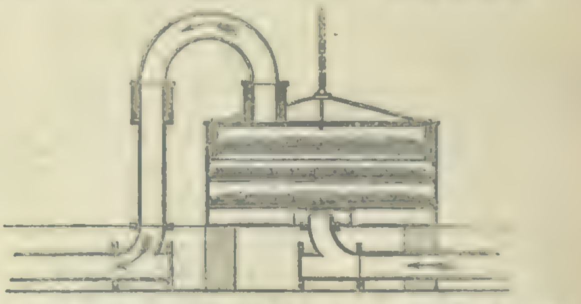
2. From the hydraulic main the gas passes at an average temperature of 120° Fahr. into the *condensers*. The condensers in the best modern works are formed by means of a series of vertical pipes, whose lower ends dip in water for the purpose of arresting the passage of the tar carried over, and which are connected by a second series of inclined pipes passing from the bottom of the first vertical pipe to the top of the second pipe. In its passage through these pipes the gas parts with some portion of its heat by radiation (and therefore the diameter of the vertical pipes should be made as large as possible) until at last, at the final exit pipe, the gas is lowered in temperature to about 60° (but

never below 45°). After leaving the condensers, the gas sometimes passes into the *scrubbers*, which usually consist of a series of shelves covered with screened porous coke; and the gas, passing through these materials, and being in its passage exposed to the action of a stream of water filtering constantly through the coke, parts with the remaining portion of its tar and a considerable portion of the ammonia it holds in solution. In large works, what is called a *washer* is often used instead of a scrubber, and in it the gas is made to pass through a solution of muriate of manganese, whose action upon the ammonia is the same as, or even more effectual than, that of the scrubber. From thence the gas passes into the *purifiers*, where the sulphuretted hydrogen, and many of the remaining ammoniacal elements it may contain, are eliminated, so that on leaving the purifiers the gas is fit to be passed through the *station-meter* into the *gas-holders* in a state adapted for household consumption. As a general rule, the exposed surface of the condensers should be in the proportion of 150 feet superficial to every 1000 feet of gas operated upon; but every description of coal will require a special treatment in this respect; because the more highly bituminous coals, for instance, part with the tarry matters volatilised in the retorts with more difficulty than do the ordinary coals; and it is desirable to retain as much as possible of those matters, provided that they be not exposed to deposition at any time in the course of their passage through the distributing mains.



When the gas leaves the condensers it usually contains impurities, consisting of about 1½ parts of ammonia, 8 parts of sulphuretted hydrogen, and 25 parts of carbonic acid in every 1000 measures of the gas, according to the author of the very remarkable papers on the 'Chemistry of Coal Gas,' inserted in the 2nd and 3rd vols. of the 'Journal of Gas Lighting.' For the purpose of removing these impurities it would appear that the most theoretically perfect course would be to pass the gas, firstly, through either the sulphate, or the muriate of lime, and then to pass it through the pure hydrated lime in powder. It happens, however, that some of the impurities which are retained by these forms of lime, namely, the hydro-sulphate of ammonia, and the hydro-sulphate of lime, are either extremely volatile, or are susceptible of decomposition on exposure to the air; and under such circumstances their removal from the purifiers, when the lime itself has been saturated, gives rise to so great a nuisance that in crowded districts, or in the centre of towns, it is necessary to employ some other material than lime as the basis of the purification. It is for this purpose that metallic salts have lately been introduced; and in some of the most scientifically managed works (as at Liverpool for instance), the process adopted within a very recent period, has been described as being as follows: "Common green copperas (sulphate of iron) is put into a mill, a little water being added to make it into a pasty mass. Slaked lime is then added, in the proportions of one part of lime to two of copperas, with water sufficient to make the whole, when ground together, of the consistency of a stiff paste. In this state it is removed, and cut into pieces with a spade, and as it dries it forms a powder which consists of sulphate of lime and hydrated sesquinoxide of iron. The powder, after being sifted is put into the purifier, where the oxide of iron becomes reconverted into sulphuret of iron; and that again by exposure to the air becomes reconverted into oxide of iron with a deposition of sulphur in the mass. This process is repeated about 28 times, and then it is found, that owing to the accumulation of sulphur, the same material cannot again be put into the purifier. In this state the material is roasted in an oven, the sulphur being in the first instance distilled from the mass, and collected in a separate form, and during the roasting process, the iron becomes red hot, and is rendered anhydrous. When taken out of the ovens the iron is thrown into open yards to cool; and is then moistened with water, in order to reconvert it into the hydrous oxide, and again put into the purifiers to commence a fresh succession of repeated actions." In the majority of the London works saw dust is mixed with the oxide of iron to increase its active surface; and in some cases the gas is made to pass through the muriate of manganese *before* passing through the iron, whilst in others it is passed through dry lime purifiers *after* leaving the iron, because the action of the latter material is not sufficiently energetic to remove all the ammonia, nor does it materially affect the carbonic acid, in its various forms of the gas.

The lime used for the purification of gas should be of the purest and richest description, such in fact as would be obtained by the calcination of chalk, or of crystalline carbonates of lime, and which expands in volume very considerably when slaked. It should be kept in store in lumps, but ground before being used, and mixed with a sufficient quantity of water to bring it into a stiff plastic state; and in that state it must be spread upon the screens of the purifiers in an even sheet of, *at the most*, 2½ inches in thickness. The successful working of the lime depends, it may be observed, on the evenness of the layer; but the most economical condition for its use is that it should expose a large surface to the gas passing through. Generally speaking, it is calculated that one bushel of ground dry lime will when slaked, spread over a surface of 25 superficial feet, and suffice for the purification of 10,000 cubic feet of Newcastle coal gas. In the oxide of iron purification, a greater surface is required than when lime only is used; but the proportion usually adopted is to make the area of the purifiers such that they should present a surface of one superficial foot to every 150 cubic feet of gas they are intended to pass: and the diameter of the connecting pipes is made in inches, equal to the square root of the area of the purifiers in feet superficial. The use of wet lime purifiers is now so universally abandoned, that it is not worth while to enter into a description of the mode of forming or of working them.

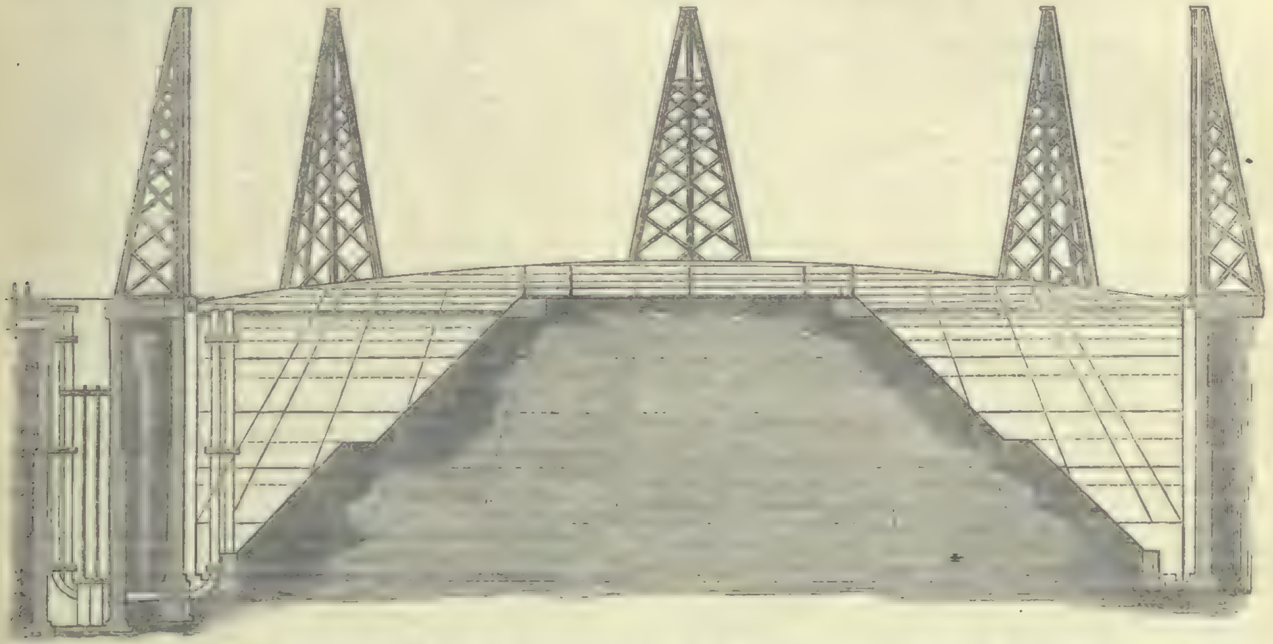


One of the most important duties of the manager of a gas factory is to ascertain that his purifiers operate successfully, and for this purpose he should frequently test the gas by means of paper, prepared by being steeped in a solution of acetate of lead in distilled water, one of the best tests for sulphuretted hydrogen. The papers should not be changed in colour by contact with the gas in the last of the series of purifiers. Sometimes papers steeped in a solution of the nitrate of silver are used as tests of the purity of gas from sulphuretted hydrogen. Test papers of litmus are used to detect ammonia, or carbonic oxide.

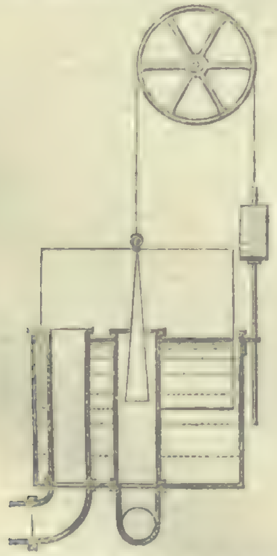
It may be as well here to add that the order in which the gas is made to pass through the purifier and the scrubber, is frequently the reverse of the one described above; and in small works the use of the scrubber is often entirely dispensed with.

3. The first operation which it is desirable to adopt in the storeage of gas, is to pass it through the station meter, in order to be able to control the working of the retort house, and to check roughly the consumption in the mains and the private distribution. For the former purpose it is necessary that the wheel-work of the meter should carry a "tell-tale," by means of which the passage of the gas is recorded in such a manner as to allow the rate of working, hour by hour, to be identified. The value of the station meter, as a check upon the actual consumption, must vary in a marked degree with the circumstances of the localities, and the mode of manufacture; for the rate of leakage, and the amount of condensation, which may take place after the gas should have passed the meter, differ in almost every town. It is, however, by no means rare to find that the loss, known in gas-working accounts, under the name of "unaccounted for gas," amounts to as much as 20 per cent. of the total quantity passing through the station meter; and the efforts of the superintendent must be earnestly directed to reducing it to a minimum. Even if a portion of the loss be attributable to the condensation of the holder and pipes, it argues an unsatisfactory state of working; for the temperature of the gas ought to have been lowered, before it was passed into the purifiers, to such a point as to render any subsequent condensation impossible unless in intensely cold weather.

The gas holder is a large wrought-iron vessel, either of one or more lifts, according to the nature of the locality (but wherever it is possible, of only one), which should be made large enough to hold one day's normal consumption (at the period of the shortest days) of gas. The holder is, in fact, an inverted cup, working in water, and in a close brick or iron tank, and rising by the elasticity of the gas entering through the inlet pipes; the discharge taking place through the exit pipes to the *governor*, by the mere weight of the holder. The pressure required to raise a holder is ascertained by the formula $p = \frac{w}{a\,5{\cdot}2}$ in which p = the pressure in inches (of a column of water); w = the weight of the holder in pounds; and a = the area of the water surface in feet; the constant 5·2 is the weight in pounds of a superficial foot of water one inch thick. The effluent pressure is found by the formula $p = \frac{547\,w}{d^2}$, in which p and w represent as before the pressure and weight, and d = the diameter of the holder in feet; the constant 547 representing the weight of a column of water in inches, of the area of the holder. Strictly speaking it would be necessary to allow for the levity of the gas, and for loss of weight in the sides of the holder as it may descend; but these considerations are so habitually neglected in practice as to justify the reference of the practical student to Clegg's 'Practical Treatise on the Manufacture of Coal Gas,' for further details.



The *Governor* is a machine for the purpose of regulating the pressure upon the outlet pipe, according to the hours of the day, and the draught upon the mains; and one of these machines must be placed at least upon each leading main of a town distribution, large or small. There are numberless patents for the construction of governors; but practically the system described by Clegg is the best, and therefore a sketch of it is appended. Its action and principles are described in detail in the work above mentioned.



Attached to the outlet-pipe of the governor there should be placed a *self-registering pressure gauge*, in order to control the operations of the men charged with the regularisation of the pressure; and one or more ordinary pressure gauges should be placed upon the leading main, for occasional observations. The self-registering gauge invented by the late Alexander Wright is one of the best, if not actually the best, instrument of this description.

4. The distribution of gas is effected by means of cast-iron mains, in all cases where their diameter exceeds 2 inches; and indeed in all cases where the pipes would be exposed to the action of moisture it is preferable to employ cast, rather than wrought, iron for street mains, even at the risk of employing larger ones than would theoretically be required. The service pipes, or those through which the gas is led into the consumer's meters, are, however, almost always of wrought iron when the diameter exceeds half an inch; below that dimension they are either made of tin or of composition, on account of the greater facility with which they can be bent to the abrupt curves frequently required in house fittings. The joints of the cast-iron pipes are usually of the description known as *socket-joints;* those of the wrought-iron pipes are of the description known as *screw-couplings;* whilst those of the smaller pipes are made by soldering in the ordinary way. The wrought-iron services are tapped and screwed into the cast-iron mains, and the composition pipes are joined to the wrought-iron ones by means of a brass screwed end, which is run upon the composition and fits into a female screw on the service pipe.

Before describing the laws which are now admitted with respect to the flow of gas in pipes, it may perhaps be advisable to make some remarks upon the quality, and the mode of manufacture, of gas mains; because the economical results of any operation of this description must, after all, greatly depend upon the manner in which those mains discharge their functions. It has been stated above, that the "unaccounted for gas" frequently amounts to as much as 20 per cent. of the total quantity made; and as very probably one-half or one-third of this loss is to be attributed to the permeation of the gas through the mains, it becomes a matter of serious importance to prevent such a loss. The principal difficulty lies in this case, as in so many other practical ones, in the prices of the various goods considered; and gas companies are too often tempted to use cheap porous pipes, obtained from first runnings, rather than incur the expense of sound second runnings. This is a very mistaken economy; and it may be laid down as a rule in these matters, that no gas mains should be allowed to be made in any works where a blast furnace exists; all mains should, in fact, be made from second runnings, and under the immediate inspection of the engineer of the gas-works; and they should all be cast vertically, with a requisite length of feeder to ensure the solidity of the metal. The very conditions of manufacture of wrought-iron pipes render them less likely to be porous than cast-iron ones frequently are; but the cheap composition pipes are so fearfully defective, that the greatest precautions should be taken in their application, and none but the most respectable and most experienced gas-fitters should be employed. No doubt many of the sad accidents recorded, of explosions in houses, are to be attributed to the use of inferior composition service pipes for the distribution of gas.

In arranging the dimensions of the mains of a gas distribution it is to be observed, first, that there is an economy of working expenses, in making the mains rather larger than would theoretically be required to deliver the quantity of gas they are originally intended to supply; because, in such a case, the gas might be made to work under a diminished pressure, and thus the leakage would be diminished. The diameters of the mains are to be ascertained by dividing the district to be supplied into certain sub-districts, according to their relative consumption, and then applying the formulæ $v = \sqrt{2g\frac{p}{s}}$; and $p = \frac{s}{2g}v^2$; the former for the purpose of determining the velocity of the gas due to a certain pressure; and the latter, the pressure for a given velocity. In these formulæ, $p =$ the pressure; $v =$ the velocity; $g =$ the force of gravity $= 32{\cdot}19$; $s =$ the weight of a cubic foot of the gas in pounds; but no attention is paid to the retarding effects of friction in the mains, or to those produced by bends, or other incidental causes. Taking the friction alone into account, it has been considered that the total pressure at the end of a pipe may be represented by the formula $p = \left(\frac{1}{2g} + M l \frac{c}{a}\right) s v^2$; in which the new terms, $M =$ a coefficient determined by experience to be $= {\cdot}00011$; $l =$ the length of the main; $c =$ the inner circumference of the pipe; and $a =$ its area. Clegg enters at length into the mathematical reasoning on this subject; and the reader is referred to his work for further details upon it; but it may suffice for present purposes to state that he finally quotes, for ascertaining practically the quantity discharged by a pipe, the formula $Q = 1350\, d^2 \sqrt{\frac{hd}{sl}}$; in which $Q =$ the quantity sought; $d =$ the diameter of the pipe in inches; $h =$ the working pressure in inches; $l =$ the length of the pipe in yards; and $s =$ the specific gravity of the gas compared to that of atmospheric air as unity. Provided the radius of the bends upon a length of main be large, there is little necessity for taking them into account; and indeed the simple precaution of making the diameter of the pipe rather larger than would theoretically be required, would obviate any necessity for so doing.

Under any circumstances, when a town is characterised by great irregularities of level, it is desirable to insert, upon the leading mains, species of receivers provided with governors at the points where the marked changes of level occur. When, on the contrary, the town is (like those of Holland) nearly upon a dead level, and close to the water-line of the district, it becomes necessary to insert numerous syphons in order to relieve the mains of the tar and other liquids which may find their way into those mains; and in towns of this character it is desirable to give an inclination of about 1 in 600 towards the syphons. It is of course necessary to maintain an efficient seal in the syphon box, and to provide a small discharge pipe to draw off any excess of tar or water. Another detail of pipe laying, which requires to be considered, is the position of the valves to be placed for the purpose of shutting off the gas during the repairs of the mains. These valves must be placed so as to interfere with the service in the smallest possible degree; but no definite rule can be laid down in any of the matters of local detail.

In laying the pipes great care should be exercised in forming a regular and incompressible bed, and in rigidly adhering to the rates of inclination prescribed. As a general rule, the pipes for conveying gas may be laid at the depth of 2 feet from the surface; but of course the latitude of the locality considered may render it advisable to modify this law. If any water-pipes should be laid in the same street as the gas-pipes, the latter must be kept as far from them as possible, and under any circumstances they must be placed *above* the water-pipes; serious accidents have indeed occurred from the neglect of these precautions, for occasionally the gas has found its way into water-pipes, by the singular action known by the names of endosmose and exosmose, and explosions have taken place at the outlet. The greatest possible care should be taken in laying the mains to ensure the tightness of the joints, as it is at such places that the gas most commonly escapes.

The following tables may be considered to represent, first, the dimensions and weights of gas-pipes of various diameters; and secondly, the quantity of gas which pipes of the respective diameters will deliver, under ordinary circumstances, with the pressure of 1 inch.

Table I. Dimensions and Weights of Pipes.

Column No. 1 represents the diameter in inches; No. 2 the number of belts in the length of pipe; No. 3, the thickness; No. 4, the mean weight of each pipe; No. 5, the tolerated deviation of weight of each pipe; No. 6, the net length of the pipes; No. 7, the ordinary price for laying and jointing, without earthworks, calculated per yard lineal.

1.	2.	3.	4.			5.	6.	7.	
		inch.	cwt.	qr.	lbs.	lbs.	feet.	*s.*	*d.*
2	2	[illegible]	0	1	24	2	6	1	1½
2½	2	[illegible]	0	2	10	2½	6		
3	3	[illegible]	1	0	3	3	9		
4	3	[illegible]	1	1	24	4	9		
5	3	[illegible]	4	3	24	5	9	1	8
6	3	[illegible]	2	2	2	6	9		
7	1 belt under socket.	[illegible]	3	0	14	7	9	2	6½
8		[illegible]	3	3	5	8	9		
9		[illegible]	4	2	2	9	9	3	0
10		[illegible]	5	1	6	10	9		
11		[illegible]	6	0	16	11	9	3	7
12		[illegible]	7	0	5	12	9		

Table II. Showing Discharge through Pipes.

Diameter. Inch.	Cubic Feet per hour.	Diameter. Inches.	Cubic Feet per hour.	Diameter. Inches.	Cubic Feet per hour.
½	90	3	4500	9	40,500
[illegible]	160	4	8000	10	50,000
[illegible]	250	5	12,500	11	72,000
[illegible]	380	6	18,000	12	72,000
1	500	7	24,500		
2	2000	8	32,000		

With respect to the consumers' fittings, it may be as well to observe that the public lamps in streets should be made to consume at the rate of 5 feet per hour on the average of the night; and that gas companies would find it desirable to use regulators upon these lamps, both for the sake of checking the waste of gas, and of improving the light from them. As a rule, the lamp-posts in the streets of populous towns should be placed alternately on either side of the street, and at a distance of from 22 to 30 yards (measured on the axis); though in the less frequented districts, the distance asunder of the posts (measured as before) may be carried, without inconvenience, even to 60 yards. The height of the flame in the lamps should be about 12 feet above the ground line.

In private houses, the character of the fittings, and the quantity of gas burnt to light a given space, depend so much upon the taste of the consumer, and the details of the burners are exposed to such constant changes from the whims and fancies of the gas fitters, that it is impossible to lay down any positive rules with respect to them, other than a few general ones derived from the ordinary principles of lighting. Thus, it is preferable to distribute the light of a room by means of a number of burners consuming small quantities of gas, rather than to concentrate it in one central burner consuming a large quantity; because the effect of artificial light diminishes in the ratio nearly of the square of the distance from its source. Of the various kinds of burners used, the ordinary Argand burner seems, quantity of gas for quantity, to be the most convenient and the most economical. The bats-wing burners are the next in the order of relative economy; and the fish-tail burners the last. The so-called solar lamps are admirably adapted for lighting large rooms, wherein it may not be desirable to distribute the sources of light, or wherein it is desired to establish an active upward ventilation; but they are expensive, and on account of the heat they evolve, they render it necessary to adopt certain precautions in the construction of the building.

Whatever description of burner be used, attention must be paid to regulate the escape of the gas, in such wise as to prevent its issuing with too great a pressure, because in the latter case a large portion of the gas would only be partially burnt, and would thus cause much smoke. As to the asserted injury to furniture, books, &c., from the use of gas in dwellings, it is curious that in an old French work, published at Lausanne in 1770, precisely the same accusation was brought against the use of coal in fire-places as is now brought against gas; and the inference to be drawn from this tale is, that certainly the latter cannot be at fault, whilst probably there may be exaggeration in both cases. The heat of gas is also at times objected to, but if the same amount of light were obtained by any other method of artificial lighting, even greater heat would be evolved; and in either case attention is required to ensure an efficient ventilation. This is the more necessary from the fact, that by whatever means artificial light is obtained, its brilliance can only be secured by the consumption of oxygen; and therefore it is essential that an ample supply of fresh air should be introduced to maintain the combustion, if for no other purpose.

A great deal of attention has lately been directed to the question of gas-meters, and a special act of parliament has been passed (22 & 23 Vict. c. 66) to regulate them. It may suffice here to say that meters are of two sorts, dry or wet; and that the latter work satisfactorily, if kept properly filled, for a longer period than the former. Both of them, however, must now be made with such accuracy that they should only have a range of error of 2 per cent. above, or below, the mathematical quantity indicated: and if the best compensating meters be used, there need be no fear of any subsequent tampering on the part of the gas companies. It is usually calculated that the consumer's meter causes a loss of pressure from its friction equivalent to about one-tenth of an inch. [See Meters, Water and Gas.]

5. The accessory buildings required for a gas factory, in addition to those required for the station meter and the governor, are merely those required for storing the coal, for receiving the fresh and the spent lime, and the coke and tar for sale; and occasionally some rooms for experiments upon the quality, and the chemical composition, of the gas; though in small works these rooms are but rarely required. If the works should be placed at any distance from the source of supply of fuel, the size of the coal sheds should be made sufficient to contain about three months' consumption. The coke shed need not be large, for it is decidedly the interest of the maker to sell it at once; and the stock of tar should at all times be kept as low as possible, on account of its inflammable nature. The lime-sheds also do not require any great capacity, but they should be weather-proof.

The dimensions of the chimney must be calculated according to the ordinary laws of the motion of heated elastic fluids, so as to ensure an efficient draught under the retorts without wasting fuel. Lofty chimneys are usually mistakes in gas-works, and it is a common maxim amongst practical engineers, that the profits are in the inverse ratio of the height of a chimney. In fact, in an open country a height of 45 or 50 feet is sufficient for a chimney serving for four beds of five retorts each. And here, perhaps, it may be as well to observe that it is in executing the foundations for the retort beds, the chimney stalk, and the gas holder, that the greatest difficulties arise in practice; and they require all the attention and the skill of the engineer.

In most country factories residences are provided for the workmen who are constantly employed; a small office and store room is constructed; and rooms are provided to receive a stock of meters, and of fittings; for the country companies in many cases are obliged to retain this branch of trade in their own hands, in order to secure its proper execution. Sometimes a board-room, and a meeting-room, are also provided.

The operation of testing the quality of a gas, with respect to its illuminating properties, is an operation of so delicate and so important a nature, that it may be desirable to dwell a little upon this part of the science of Photometry, at least so far as may be necessary to explain its ordinary application in commercial affairs.

The principles upon which the photometers in general use are constructed, are based upon the law that "the power of a luminous body to light a given space is directly proportional to the intensity of the light itself, and inversely proportional to the square of the distance of the point of observation from it;" and its application is obtained by causing the two sources of light it may be desired to compare, to shine upon the respective sides of a thin and partially translucent body. When the illumination of the exposed surfaces of the latter is equal, that is to say, when neither of these faces possesses a greater degree of luminosity than the other, the illuminating powers of the sources of light with respect to the interposed body are said to balance one another. If then one of the sources of light be a lamp, or candle, possessing known illuminating properties, it is easy to calculate the relative value of the other, in terms of the power of the standard, according to their respective distances from the interposed object. The difficulty, of course, lies in the selection of an invariable standard for this purpose, and the choice of gas engineers varies between wax and spermaceti candles, or the Carcel lamp. In England, the standard usually adopted is the spermaceti candle, burning 120 grains per hour; in France, the standard is frequently the Carcel lamp, burning 42 grammes (2·4 oz.) of rape oil per hour; and when the light of either of those illuminating bodies is to be compared with gas, the latter must be admitted in certain definite quantities (usually about 5 cubic feet per hour), and under a carefully regulated pressure.

The thin partially illuminated screen above referred to, in the Bunsen photometer (the one usually adopted with various modifications in England), presents a surface which is white, but nearly opaque on the circumference, and perfectly translucent in the centre. The preparation of this disk is a matter of great delicacy, for the translucent part should differ as little as possible in colour from the rest of the surface, when the illumination of its sides is equal. Dr. Fyfe, and the majority of English makers of photometers, use cream-coloured writing-paper for the screen, and they mark the translucent centre covering it with a solution of spermaceti in oil of naphtha equally diffused over its surface; the diameter of this translucent centre is usually about the same as that of a half-crown piece. In the photometers made by the late Alexander Wright and his successors, the screen was placed in the middle of a cylindrical shade, blackened on the inside: and it worked upon a bar graduated so as to express at once the value in candles and decimal parts of candles, of the legal standard, of the light experimented upon. Great care ought to be taken to exclude any extraneous rays of light derived from reflection from the sides of the room, or from the surface of the graduated bar; so that, in fact, none but the direct rays from the respective sources of light should be allowed to impinge upon the screen. The length of the bar in Wright's photometer is about 100 inches; in Church & Mann's photometer it is considerably less; and, indeed, for some reasons the latter instrument seems to be the most convenient one of its kind.

It is curious that notwithstanding the importance of the operations of photometry, in many cases of disputed contract, no attempt has been made to ascertain the limits of what M. Quetelet calls "the personal equation of observation" in them. The powers of every individual to appreciate degrees of luminosity differ, more or less; and the singular discrepancies in the results of the recorded observations on this subject may be to some extent accounted for on this ground.

A series of tables of the illuminating powers of the gas obtained from the coals generally used in England, will be found in the new edition of Clegg; a book which, by the way, entirely supersedes all other works upon the subject. In the same work there are some equally interesting tables of the composition of the various coals themselves, and a valuable chapter upon the modes of dealing with the residual products of the manufacture of gas. The reader is, therefore, referred to Clegg's 'Practical Treatise on the Manufacture of Coal Gas,' 1859; to D'Hurcourt's 'Traité de l'Eclairage au Gaz,' 1845; Peckston, 'On the Theory and Practice of Gas Lighting,' 1823; and Accum's 'Practical Treatise on Gas Light,' 1815. In the 'Journal of Gas Lighting,' a vast amount of useful practical and theoretical information may be found on this subject; and likewise in the 'Practical Mechanics' Journal.' The latter, particularly, contains some elaborate articles on the various systems introduced by Mr. Bowyer, of St. Neot's, for the purpose of applying gas on a suitable scale for the economical lighting of small towns, and even of private houses. Some notion of the national importance of the gas industry may be formed from the fact that there are in existence in the United Kingdoms about 1000 gas companies, and that it is able to support special journals, not only in England, but also in France, Germany, and the United States.

GASES, COLLECTION OF. The collection and preservation of gases form a class of chemical operations so essentially distinct from those employed in manipulations with the other two forms of matter, that it will be useful to describe them in a separate article.

The chief difficulty to be overcome in manipulations with gases is their diffusibility or tendency to mix with atmospheric air, a property which gases possess to such an extent that comparatively few substances are capable of entirely resisting the passage of gaseous matter through their pores. This diffusibility renders the collection of gases by displacing one gas, contained in any vessel, by means of another, always an imperfect and frequently an impracticable operation; nevertheless, where the two gases differ considerably in specific gravity, and when absolute purity is not required, this process may sometimes be resorted to with advantage.

Collection of gases by gaseous displacement.—In this process the gas displaced is always atmospheric air, and in order to apply it successfully it is necessary that the gas should be generated in a copious stream, and it is also desirable that its specific gravity should differ considerably from that of the atmosphere. Tall and narrow glass cylinders or bottles are best adapted for this purpose. If the gas to be collected be heavier than air, the jar in which it is received must be placed with its mouth upwards, and the tube conveying the gas must terminate at or near the bottom of the jar, as in *fig.* 1. If, on the other hand, the gas be lighter than air, the jar must be inverted, and the gas delivery tube must reach as before to the closed end of the cylinder, as in *fig.* 2.

Fig. 1.

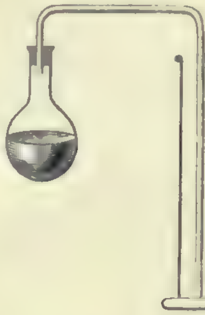


Fig. 2.

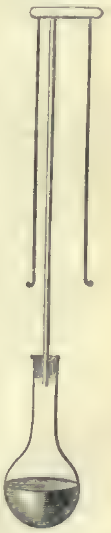
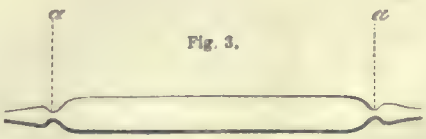


Fig. 3.

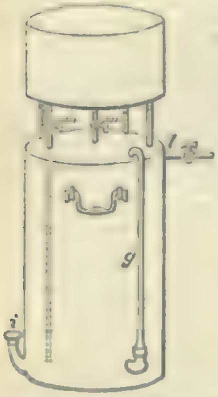


A modification of this method is frequently employed in the collection of gases for analyses, where a high degree of purity is indispensable. The gas-delivery tube is connected with a glass tube or series of tubes drawn out at both ends, as shown in *fig.* 3, and the current is continued until the last traces of air are expelled, an operation which is facilitated by connecting the extremity where the gas is issuing with a long caoutchouc tube, which prevents the retrogression of air by diffusion. When the current has been continued for a sufficient length of time it is interrupted, and the tube is rapidly sealed up hermetically, by the application of a mouth-blowpipe flame to the narrowest portions, *a a*.

Collection of gases by displacement of water.—This is by far the most common method in use, although without great care and the employment of recently boiled water it is impossible to preserve the gas free from admixture with air, because all gases being more or less soluble in water, a transference of the gas into the air, and *vice versâ*, is constantly taking place through the confining liquid. The most simple mode of collecting gases by this process consists in filling a glass jar, such as that shown in *fig.* 1, with water, inverting it on the shelf of a pneumatic trough, and then bringing the extremity of the gas delivery tube beneath the mouth of the jar; the gas then bubbles through the water, ascends into the upper part of the jar, and displaces the water with which the latter was previously filled.

Larger quantities of gases are collected in *gasholders*, or *gasometers*, by this method. *Fig.* 4 represents the gasholder most generally employed for experimental purposes. It consists of a cylindrical copper vessel, closed at top and bottom, and at about 6 inches above it a second shorter cylinder, open at top, is fixed upon suitable supports. The two cylinders are connected by means of two tubes, *m*, *n*, furnished with stopcocks; *m* passes nearly to the bottom of the lower cylinder, whilst *n* terminates under its cover. At *l* there is also a stopcock and short tube, and at *i* there is a larger orifice which can be securely closed by means of a screw-plug.

Fig. 4.



To use this gasholder, the plug *i* must be screwed into its place, all the stopcocks opened, and water poured into the upper cylinder. The water will descend through the tube *m*, and expel the air from the lower cylinder through the stopcocks, *n*, *l*; when water issues from the latter, the lower cylinder is filled: *m*, *n*, and *l* must now be closed, and the screw-plug, *i*, being removed, the apparatus is ready for the collection of gas. The tube conveying the latter must be inserted into *i*; the bubbles will now ascend to the upper part of the cylinder, displacing a corresponding volume of water, which will flow out of *i*. The quantity of gas collected is conveniently seen by means of the glass gauge-tube, *g*. When the necessary amount of gas has thus been received in the holder, the delivery tube is removed from *i*, and the screw-plug replaced. The gas may at any time be expelled from this holder for experimental purposes, either through the tube *n* into jars filled with water and inverted over its orifice, or through *l* in a continuous stream, which is often desirable. The expulsion of the gas through either of these orifices is effected by opening the stopcock, *m*, and keeping the upper cylinder supplied with water. It is scarcely necessary to remark that such gases only as are sparingly soluble in water can be collected by this process.

Collection of gases by displacement of mercury.—This is by far the best process for the collection of gases in a state of perfect purity, although it is less frequently employed than the other two processes, owing to the difficulty of manipulating with a heavy fluid like mercury. The process exactly resembles in principle the collection by displacement of water, but owing to the high specific gravity of mercury, vessels of small size only can be used; hence glass tubes of a diameter varying from half an inch to 1¼ inch are generally employed. Care must be taken not to allow the gas-delivery tube to dip too deep into the metal, otherwise the great pressure upon the gas-generating apparatus may endanger the tightness of the joints. This method may be applied to all gases except chlorine and hydrofluoric acid.

In addition to these methods of collection, many gases may be conveniently stored up in caoutchouc or mackintosh bags, when purity is not of importance; but they should not be retained in such bags more than 48 hours, otherwise they become mixed with considerable quantities of air. Care should be taken not to collect coal-gas in caoutchouc, as the latter becomes softened and partially dissolved.

GASES, LIQUEFACTION OF. We are indebted chiefly to Professor Faraday for our knowledge of liquified and solidified gases. The method which he employed consisted in combining the condensing power of mechanical compression with that of very considerable depression of temperature. The first object was attained by the successive action of two air-pumps; the first having a piston of one inch in diameter, by which the gas to be condensed was forced into the cylinder of the second pump, the diameter of whose piston was only half an inch. The tubes into which the air, thus further condensed, was made to pass, were of green bottle-glass, from one-sixth to one-quarter of an inch in external diameter, and had a curvature at one portion of their length adapted to immersion in a cooling mixture: they were provided with suitable stopcocks, screws, connecting pieces, and terminal caps, sufficiently air-tight to sustain a pressure of fifty atmospheres. Cold was applied to the curved portions of the tube by their immersion in a bath of Thilorier's mixture of solid carbonic acid and ether. The degree of cold thus produced, when the mixture was surrounded by the air, was —106° Fahr., by an alcohol thermometer. But on placing the mixture under an air-pump, and removing the atmospheric pressure, leaving only that of the vapour of carbonic acid, which amounted only to one twenty-fourth of the former (that is, to the pressure of a column of 1·2 inch of mercury), the thermometer indicated 166° below zero. In this state the ether was very fluid, and the bath could be kept in good order for a quarter of an hour at a time. Mr. Faraday found that there were many gases which, on being subjected to cold of this extreme intensity, condensed into liquids, even without a greater condensation than that arising from the ordinary atmospheric pressure, and they could then be preserved, sealed up in glass tubes in this liquid state. Such was the case with chlorine, cyanogen, ammonia, sulphuretted hydrogen, arseniuretted hydrogen, hydriodic acid, hydrobromic acid, carbonic acid, and euchlorine. With respect to some other gases, such as nitric oxide, fluoride of silicon, and olefiant gas, it was difficult to retain them for any length of time in the tubes, in consequence of the chemical action they exerted on the cements used in the joinings of caps, and other parts of the apparatus. Hydriodic and hydrobromic acids could be obtained either in a solid or liquid state. Hydrochloric acid gas did not freeze at the lowest temperature to which it could be subjected. Sulphurous acid froze into transparent and colourless crystals, of greater specific gravity than the liquid out of which they were formed. Sulphuretted hydrogen solidified in masses of confused crystals of a white colour, at a temperature —122° Fahr. Euchlorine was easily converted from the gaseous state into a solid crystalline body, which by a slight increase of temperature melted into an orange red fluid. Nitrous oxide was obtained solid at the temperature of the carbonic acid bath *in vacuo*, and then appeared as a beautifully clear and colourless crystalline body. Mr. Faraday conceives that in this state it might, in certain cases, be substituted with advantage for carbonic acid in frigorific processes, for arriving at degrees of cold far below those hitherto attained by the employment of the latter substance. Ammonia was obtained in the state of solid white crystals, and retained this form at a temperature of —103°. The following liquids could not be made to freeze at —166°: chlorine, ether, alcohol, bisulphide of carbon, caoutchoucin, camphor, and rectified oil of turpentine.

The following table, chiefly from Miller's 'Elements of Chemistry,' shows the points of liquefaction and solidification of various gases:—

Names of Gases.	Temperature of Solidification.	Pressure in Atmospheres required for Liquefaction.		
		At 32° F.	At 60° F.	° F.
Sulphurous acid . .	—105	1·53	2·54	5·16 at 100°
Cyanogen. . . .	— 30	2·37		4·00 at 63°
Hydriodic acid . .	— 60	3·97	5·86	
Ammonia . . .	—103	4·40	6·90	10·00 at 83°
Sulphuretted hydrogen .	—122	10·00		14·60 at 52°
Protoxide of nitrogen .	—150	32·00		38·40 at 35°
Carbonic acid . .	— 70	38·50		
Euchlorine . . .	— 75			
Hydrobromic acid .	—124			
Fluoride of silicon . .	—220			
Chlorine . . .		8·95	13·19	
Arseniuretted hydrogen				1·00 at —40°
Olefiant gas . . .				26·90 at 0°
Ethyl				2·25 at 37·5°
Fluoride of boron . .				11·54 at —62°
Hydrochloric acid .		26·20		40·00 at 50°

Hydrogen, nitrogen, carbonic oxide, and nitric oxide, have been submitted to pressures of upwards of 800 atmospheres without exhibiting signs of liquefaction.

GASHOLDER or GASOMETER. [GAS, MANUFACTURE OF.]

GASOMETER. [GASES, COLLECTION OF.]

GASOMETRIC ANALYSIS. *Gas analysis. Eudiometrical analysis. Eudiometry.* This branch of chemical analysis originated in the attempts of Fontana, Landriani, Scheele, Priestley, Gay Lussac, and others, to determine the volume of oxygen in samples of atmospheric air taken from various localities. The imperfect methods then used led these observers to believe that there was considerable difference in the per-centage of oxygen contained in the air resting over different portions of the earth's surface, and it was imagined that these differences were closely connected with the unhealthiness or salubrity of various places. Hence the name *eudiometer* (from *εὔδιος* and *μετρεῖν*, measurer of the goodness of air) was given to the instrument used for these determinations.

The principle upon which the use of the eudiometer was made to depend, so far as atmospheric air and oxygen gas are concerned, was that of exposing them to the action of some substance, whether solid, fluid, or gaseous, which, on account of its affinity for oxygen, combined with the latter, leaving the gases with which it was mixed unacted upon.

The eudiometer invented by Dr. Priestley arose from, and was connected with, his great discovery of oxygen gas and the fact which he ascertained of its absorption by another gas, which he called nitrous air, since called deutoxide or binoxide of nitrogen, or nitric oxide gas.

This gas may be considered as nitric acid deprived of a large portion of its oxygen, which is effected by dissolving a metal in it, as, for example, copper, silver, or mercury; and of these the last mentioned yields the gas in the greatest purity. The nitric oxide thus obtained being disposed to regain the oxygen which the metal has taken from it, absorbs it with great facility from all such gaseous mixtures as contain it; the evidences of its action are the formation of a red vapour, condensation of volume, and the reproduction of one of the acids of nitrogen; and the quantity of oxygen absorbed is determined by the degree of condensation which is produced by its action.

Dr. Priestley's method was extremely simple: he took a phial capable of holding about an ounce of water, filled it with water, and displaced the latter with atmospheric air, or with the gaseous mixture to be examined; the volume of this being noted, it was transferred, over water, into an air-jar about an inch and a half in diameter. An equal volume of nitric oxide was added to it, and they remained together for about two minutes: if the diminution was very considerable, another volume of nitric oxide was added. When this part of the process was over, the gas was transferred to a glass tube about two feet long, one-third of an inch in diameter, and graduated into 10ths and 100ths. After noting the volume of the gas, the result was expressed in measures and decimal parts; thus, when equal volumes of common air and nitric oxide were mixed, and they afterwards occupied the space of one volume and two-tenths, Dr. Priestley, in speaking of the air so tried, said the measures of the test were 1·2 or the standard of the air was 1·2. Owing to the formation of several compounds of nitrogen and oxygen in this process it is now known to be entirely unworthy of confidence.

The eudiometer next to be mentioned is that invented by Scheele, which was probably the first proposed after Dr. Priestley's. This was a graduated glass tube containing a certain volume of air, which was exposed to a mixture of sulphur and iron-filings made into a paste with water. Although the oxygen was absorbed and the nitrogen left by this operation, yet the process was not to be relied upon; for, by the formation of sulphuric acid, which occurred by the oxidisement of the sulphur, the iron was acted upon, and water being decomposed, its hydrogen was evolved, and interfered with the results of the operation.

This plan, however imperfect, had the merit of simplicity; for the quantity of oxygen absorbed was determined at once by deducting the volume of the residual gas from that of the whole quantity submitted to experiment.

De Marté, instead of using sulphur and iron, employed a solution of sulphuret of potassium, prepared by dissolving sulphur in a solution of potash. It is stated that this solution when newly prepared absorbs a small portion of nitrogen; but the fallacy arising from this source is partially obviated by agitating the solution for a short time with a little atmospheric air previously to using it, by which it is saturated with nitrogen. A tube divided into 100 parts and immersed in the solution is sufficient for the use of it.

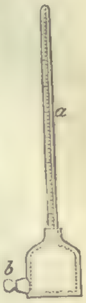
Guyton also employed sulphuret of potassium in his eudiometer, but he used it in a solid state, and applied heat to expedite its action. In this case, as when the solution is used, both the sulphur and potassium are oxidised. A description of this eudiometer, which has been but little used, is given in 'Nicholson's Journal,' 4to, vol. i.

The eudiometer of Seguin is a glass tube, about an inch in diameter, eight inches long, and open at one end. It is to be filled with and inverted in mercury; a small piece of phosphorus is then put under the open end of the tube, and by its lightness it immediately rises to the top of it, where it is to be melted by the approach of a red-hot iron. A measured portion of the gas to be examined is then to be passed into the tube; the phosphorus inflames on each addition of the gas, and the mercury rises, owing to the condensation of the oxygen. When all the gas under examination has been thrown up into the tube, the hot iron is again used to ensure the completion of the process. The quantity of the residual gas is determined by transferring it into a graduated tube, and the difference between the quantity submitted to experiment and that left after it, indicates the volume of the oxygen absorbed.

In this operation, owing to the affinity existing between the phosphorus and the oxygen, they combine and form phosphoric acid: it is however stated that the nitrogen absorbs a small quantity of phosphorous vapour, and that, owing to the expansion which this occasions, about $\frac{1}{10}$ of the volume of the nitrogen gas is to be deducted.

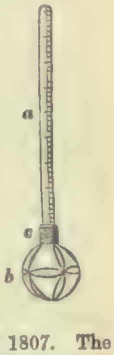
Berthollet also employed phosphorus in his eudiometer, but instead of heating it, as in the above-described method, he allowed combination to take place between it and the oxygen, by what is termed slow combustion. He exposed a stick of phosphorus fastened to a glass rod in a narrow graduated glass vessel, filled with air, and standing over water: the phosphorus immediately begins to act on the oxygen of the air, as shown by the formation of the white vapour of phosphorous acid; but this occurs without visible combustion. In six or eight hours the whole of the oxygen disappears, and its quantity is, of course, immediately apparent, making the deduction above stated from the nitrogen gas.

Dr. Hope's eudiometer is represented in the annexed figure. It is used with a solution either of sulphate of iron impregnated with nitric oxide or with solution of sulphuret of potassium. This eudiometer consists of a small bottle, capable of holding about three ounces, for containing the eudiometric fluid, and it is perforated and furnished with a stopper at *b*. Into the neck of the bottle a hollow graduated tube, *a*, closed at the upper end, is accurately fitted by grinding. It holds precisely a cubic inch, and is divided into 100 equal parts. To use the apparatus, the bottle is first to be filled with the solution to be employed, and, covering the mouth with a flat piece of glass, it is to be immersed in water; the glass being then removed, the open end of the tube containing the gas to be examined is to be inserted.



The instrument being removed from the water, is to be inverted. The gas ascending into the bottle, it is to be brought into thorough contact with the liquid by brisk agitation, by which absorption of gas occurs. To supply its place, the stopper at *b* is removed under water, a quantity of which rushes into the bottle; the stopper is then replaced, and these operations are alternately renewed till no further diminution takes place. The tube *a* is then withdrawn, the neck of the bottle being in water, and it is held inverted for a short time, and the diminution is then measured by the graduated scale.

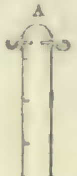
Dr. Henry has pointed out some difficulties attendant upon the use of this eudiometer, to obviate which he has substituted a caoutchouc bottle for the glass one, as shown in the annexed figure at *b*. The tube *a* is accurately ground into a short piece of very strong tube of wider bore, as shown at *c*, the outer surface of which is made rough by grinding, and shaped as represented, that it may more effectually retain the neck of the elastic bottle when fixed by waxed thread. This instrument is used in every respect in the same manner as Dr. Hope's. The only difficulty is in returning the whole of the residuary gas into the tube; but the art of doing this is readily acquired by practice.



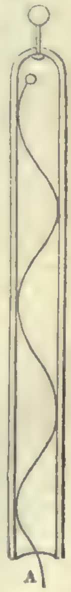
Pepys contrived a eudiometer in which a caoutchouc bottle was employed, as in Dr. Henry's. This instrument, from the inventor's statement, appears to be susceptible of great accuracy; for he states that he is able to measure an absorption of only $\frac{1}{1000}$ of the gas employed. For an account of this eudiometer, and of some experiments performed with it, see 'Phil. Trans.,' 1807. The parts are too numerous for us to insert figures of, and without them a description would be scarcely intelligible; besides, the apparatus is now superseded by others.

Having now described the use of nitric oxide, sulphuret of potassium, and phosphorus, as eudiometrical substances, and mentioned the more important instruments in which they are employed, we shall notice the eudiometer of Volta, and the eudiometric body which he made use of.

Volta's method of determining the composition of atmospheric air, or of the quantity of oxygen contained in gaseous mixtures, was by means of combustion with a known volume of hydrogen gas; for it having been ascertained that when a mixture of oxygen and hydrogen gases is fired, one-third of the diminution is owing to the condensation of oxygen, we have only to observe the measure of the contraction of volume to ascertain that of the oxygen which was present. Of Volta's eudiometer various modifications have been proposed, all agreeing however in the principle above mentioned. According to Berzelius, that invented by Mitscherlich is to be preferred, on account of the simplicity of its construction and the accuracy of its results. We shall, therefore, describe it instead of the original one, and it will at once occur to the chemical reader that it is a slight modification of Priestley's and Cavendish's detonating tubes.

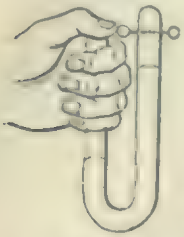


This instrument, as represented by the annexed figure, consists of a very thick glass tube, from 18 to 24 inches long, and about 4 lines internal diameter; it is graduated, open at one end, and closed at the other. Near the top (A) the tube is perforated with platinum wires, placed at such a distance as readily to allow of the passage of the electric spark between them, and externally hooked; near the orifice (B) the tube is laterally perforated and furnished with a glass cock, which is shut after filling the tube with the gas to be examined: this is, of course, to prevent the loss of gas by the expansion accompanying the detonation by the spark. When this is over, the cock is turned under either water or mercury, and the fluid rising in the tube, the condensation is exactly noted by bringing the fluid within and without the tube to the same level.



Another variety of Volta's eudiometer is represented by the opposite figure. It is more simple in its construction than the foregoing, but less certain in its results, on account of the escape of gas which occurs if it be not immersed sufficiently deep in water or mercury: it is a modification of an instrument invented by Dr. Priestley. The only additional explanation required is, that A is a moveable metallic wire with a knob at the end, which is raised near enough to the knob at the top of the instrument to allow of the passage of the electrical spark.

Dr. Ure also contrived a modification of Volta's eudiometer, which renders the experiment easy of performance by a single person. This instrument is shown by the figure. It consists of a glass siphon, having an interior diameter of from 2-10ths to 4-10ths of an inch; its legs are nearly of equal length, each being from six to nine inches long. The open extremity is slightly funnel-shaped; the other is hermetically sealed, and has two platinum wires inserted: the legs are about one-fourth to one-half an inch asunder. The instrument having been graduated, it is to be filled with water or mercury, and the gas transferred into it in the ordinary manner; then being upright, part of the fluid in the open leg is displaced by inserting a glass rod, or in some other manner. The open leg ought to contain at least two inches of air between the thumb and the mercury: this atmospheric column serves as a recoil-spring, enabling the operator to explode considerable quantities of gas without inconvenience or danger. The open leg being grasped by the hand, the thumb is to be placed lightly over the aperture, so as to close it, and at the same time to touch one of the wires; a spark taken from the conductor to the other wire passes through the gas, inflaming it, and is conducted off by the thumb and hand. The gas in expanding depresses the fluid beneath it, whilst, as already noticed, the air in the part inclosed by the thumb acts as a spring to restrain the violence of the explosion. If a charge from a jar is to be passed, then the thumb must not be allowed to touch the wire whilst closing the aperture. When the jar is charged, the wire connected with the outer coating is first to be hooked upon the eudiometer wire nearest the thumb, and securely retained there, so as not to slip during the experiment; and then the knob of the jar is to be brought to the other wire and the gas inflamed.



After explosion, when the condensation of volume ensues, the thumb will feel pressed down to the orifice by the superincumbent atmosphere. On gradually sliding the finger to one side and admitting the air, the mercurial column in the sealed leg will rise more or less above that in the other; mercury is then to be poured in till the equilibrium is restored, and the resulting volume of gas is then read off.

Dr. Ure states that with the above instrument he has exploded half a cubic inch of hydrogen mixed with a quarter of a cubic inch of oxygen, as also a bulk nearly equal of an olefiant gas explosive mixture, without any unpleasant concussion or noise.

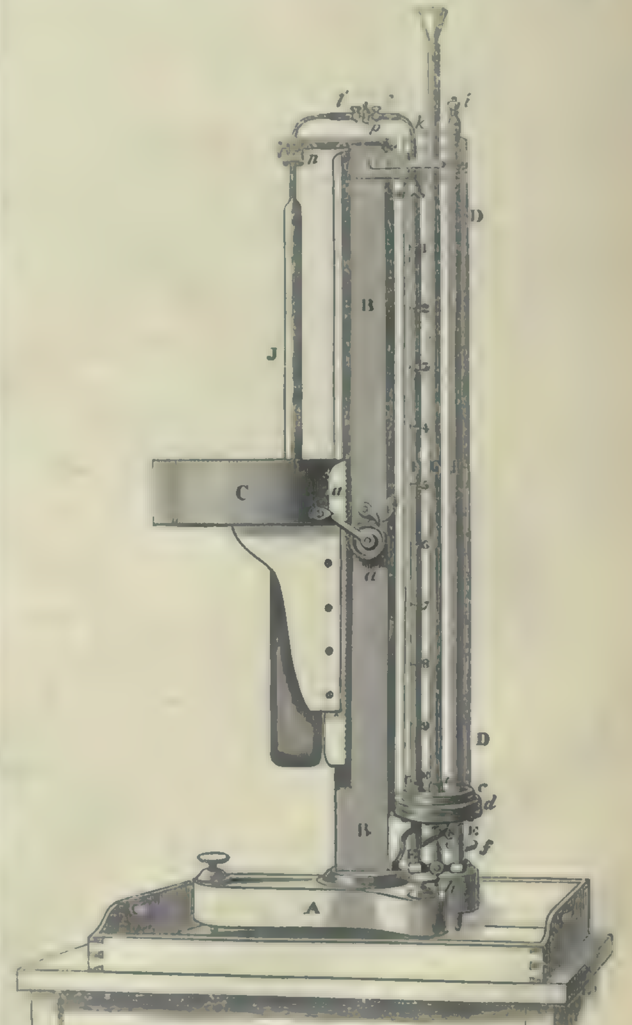
Döbereiner suggested a eudiometrical process, founded on his curious discovery of the property which spongy platinum possesses of causing the combination of oxygen and hydrogen gases. In this eudiometer the combination occurs without explosion, and yields results of considerable accuracy. Döbereiner found that when the spongy platinum was mixed with certain substances, so as to prevent its immediate and explosive action, it caused the oxygen and hydrogen to combine with moderate rapidity. The late Dr. Henry, who performed a most important and accurate series of experiments on this eudiometrical process, recommended a mixture of three parts of spongy platinum and two of fine china clay made into a paste with water and moulded into spherules about the size of a pea; these were fastened to a platinum wire, that they might be removed after the action was over. They should be heated and suffered to cool a short time before use: they suffer no loss of power, and possess the great advantage over the electric spark, that they act upon gaseous mixtures which contain so little oxygen and hydrogen that they cannot be fired. The late Dr. Turner ascertained that it was possible to determine the presence of $\frac{1}{100}$ of hydrogen or oxygen in a gaseous mixture; whereas, when these gases formed $\frac{1}{11}$ of a mixture, they could not be detected by electricity. The effect takes place more rapidly in large than in small tubes.

There are various gases which impede the action of the platinum balls. It appears from the experiments of Dr. Henry, that when the compound combustible gases, mixed with each other, with hydrogen, and with oxygen, are exposed to the balls of platinum, the several gases are not acted upon with equal facility: that next to hydrogen carbonic oxide is most disposed to unite with oxygen, then olefiant gas, and lastly, light carburetted hydrogen.

Dr. Henry observed, that the property inherent in certain gases of retarding the action of platinum, when they are added to explosive mixtures of oxygen and hydrogen, is most remarkable in those which possess the strongest attraction for oxygen. Heat occasions the platinum balls to act in many cases in which no combination would occur without it.

The instruments and methods above described were not only almost exclusively limited to the determination of the oxygen in atmospheric air, but they were also both imperfect and incorrect, and the analysis of gaseous bodies cannot be said to have become organised into anything like a system until Professor Bunsen applied himself to its improvement, which he effected less by the use of new instruments than by the perfection of the old ones, and the correction of the numerous sources of error which rendered the results of earlier experimenters so little trustworthy. To this accomplished chemist, to Regnault and others, this branch of chemical analysis owes its present state of perfection, which is rarely equalled and never surpassed in other departments of analytical chemistry.

Ingenious instruments for the analysis of gases have been contrived by Messrs. Regnault and Reiset (see 'Annales de Chimie et de physique,' t. xxvi., p. 333) and by Drs. Williamson and Russell ('Philosophical Magazine,' vol. xvi., p. 524) but in this article we shall confine ourselves to the description and use of an apparatus invented by Messrs. Frankland and Ward, which may be employed in all the operations of gaseous analysis, and which is represented in the annexed figure. A is a tripod base furnished with levelling screws and carrying the vertical pillar B B which supports on one side the moveable gutta percha mercury trough C, with rack and pinion *a a*, and on the other the glass cylinder D D with its contents. This cylinder is 36 inches long and 4 inches internal diameter; its lower extremity is cemented into an iron ring *c*, the under surface of which permits of being screwed watertight upon the iron platform *d* by the intervention of a caoutchouc ring. The circular platform *d* is pierced by three tubes which terminate below in the T piece E E. Into these tubes are screwed the steel caps *c c c* which receive the open extremities of the glass tubes F, G, H. The T piece E E is furnished with a three-way cock *f*, and with a simple cock *g*, by means of which the tubes in D D can be connected either with each other or with the exit nozzle *h*. Of the glass tubes F G H, one F is only slightly shorter than the containing cylinder, another H is 3 or 4 inches longer, whilst G rises at least 6 inches higher than the latter. F and H are each about 15 millimeters diameter; G is somewhat wider and open at top. H has a millimeter scale etched upon it, and its upper extremity terminates in a small funnel *i*, the throat of which can be closed by a ground stopper. The



tube F terminates in the capillary tube *k* which is cemented into the steel stopcock *l*; two platinum wires fused into this tube at *m* admit of an electric spark being passed through any gaseous mixture it may contain. This tube is graduated into ten divisions of equal capacity. A tube J, open below and terminating above in the stopcock *l'* is held in its place by the clamp *n*, and can be connected with the stopcock *l* by the junction piece *p*.

The instrument must now be levelled, and the height of each division upon F above the zero point of the millimeter scale on H must be determined by opening their upper extremities and filling them with successive quantities of mercury up to the different divisions upon F, noting at each division the height of the mercury in H. Before use, the cylinder D D must be filled with water, and the interior of the tubes F and H moistened with a few drops of distilled water introduced through the stopcock *l* and the funnel *i*. The three tubes being now placed in communication, mercury must be poured into G until it rises into *i*, when the stopper must be firmly inserted. As soon as the mercury flows from *l* that stopcock must also be closed. The tube J is then to be filled with mercury and attached by the clamp *n* and junction piece *p* to the stopcock *l*, and a glass tube about 2 feet long passing through the table upon which the apparatus stands, and terminating in a vessel below, being attached to the exit pipe *h*, the instrument is complete.

In order to illustrate the method of using this apparatus, let us suppose that an analysis of atmospheric air has to be made. Three or four cubic inches of atmospheric air, previously freed from carbonic acid, are thrown up into the tube J, and passed through the stopcocks *l l'* into the tube F, a transference which is accomplished by placing the three-way cock *f* in such a position as to connect F with the exit tube *g*, through which the mercury flows out as the gas enters above. This operation is facilitated by simultaneously raising the trough C. As soon as the transference is complete the cock *l* is shut, and *f* so placed that F and H are connected with *h*. Mercury is allowed to flow from *h* until a vacuum of 3 or 4 inches in length is produced in H and the highest point of the metal in F stands somewhat lower than one of the divisions upon that tube. The cock *f* must now be reversed, and *g* slightly opened so as to allow mercury to flow into F and H until its highest point in F exactly coincides with one of the divisions. The height of the quicksilver in H must now be exactly determined by reading through a horizontal telescope placed at a distance of about 6 feet. If from the number thus read off the height of the particular division at which the mercury stands in F be deducted, the remainder will represent the true volume of the gas; since the tension of aqueous vapour in F neutralises or corrects that in H, whilst the temperature of the tubes being maintained constant during the course of the analysis by the water in D D, no correction for variation of temperature requires to be made, and as the tubes in which the volumes are determined are completely shut off from all communication with the atmosphere, the barometrical changes which would otherwise affect the volume of the gases are entirely without influence upon this apparatus.

Hydrogen in the proportion of half the volume of the air used must now be passed into J, and thence into F, where the volume of the mixed gases must be again determined as before. An electric spark must now be passed through the mixture in F by means of the platinum wires at *m*. A slight explosion follows, and a considerable contraction in volume of the gaseous mixture also occurs; this contraction must be accurately measured by a new determination of the volume of the gases remaining in F. One-third of the contraction thus measured represents the volume of oxygen contained in the air submitted to analysis, and as the air employed consisted only of oxygen and nitrogen, it follows that the estimation of the former gas determines also the volume of the latter.

Having thus described the construction of this instrument, we will now proceed to notice the methods by which, with its aid, the different gases are separated from each, and the volume of each determined.

The volumes of the separate constituents of a gaseous mixture can be ascertained either 1st, by direct determination; or 2nd, by indirect determination.

1.—*Direct determinations.*

The chief gases which permit of being thus determined are the following:—

Carbonic Acid.
Oxygen.
Olefiant gas, or Ethylene.
Carbonic Oxide.

On the supposition that all these gases were present in a mixture to be analysed, the following operations would be necessary for the direct determination of each.

First, pass a convenient volume of the gas into the tube J, allow it to pass over into F until the mercury rises into the bend of the capillary tube *n l'*, and determine its pressure at any convenient mark on the latter tube; then pass up into J by means of a curved pipette, one or two drops of a concentrated solution of caustic potash, which will immediately ascend to the top of the tube. Now return the gas into J, and let a quantity of mercury trickle over after it. As the gas depresses the mercury in J, the caustic potash moistens the interior surface of that portion of the tube occupied by the gas, whilst the drops of mercury falling over from *k* greatly facilitate the action of the alkaline liquid by bringing every portion of the gas into contact with it. In three minutes the whole of the carbonic acid is absorbed, and the residue must now be transferred back into F for re-measurement of pressure at the same mark upon F, great care being taken that the caustic potash solution does not pass the point between *n* and *l'* to which the mercury was allowed to rise in the previous transference. The difference between this and the former measurement represents the volume of carbonic acid absorbed by the caustic potash.

From two to six drops of a strong solution of pyrogallic acid must now be thrown up into J, and the gas being again brought over from F, the oxygen which it contains will be completely absorbed in a few minutes, the liquid in J becoming of an intense blood-red colour. The re-measurement of the gas, with the same precautions as before, gives the volume of oxygen in the mixture.

The gas being retained in F, the tube J must be detached from the apparatus, thoroughly cleansed, by washing with water, and then dried, first with bibulous paper, and afterwards by a current of warm air, care being also taken to get the capillary tube perfectly dry. The tube whilst still warm must be completely filled with mercury by immersing it as deep as possible in the well of the trough C, and then applying suction to the orifice of the cock *l'*. Being now attached as before to *l*, the residual gas in F must be completely drawn over into it, but in such a manner as to avoid the ingress of mercury which might carry over with it some moisture from the tube F. The absorption of olefiant gas must now be effected by introducing into J a coke bullet saturated with a solution of anhydrous sulphuric acid in nordhausen sulphuric acid. The coke bullet is made by placing the bent end of a piece of thin platinum wire in a bullet-mould about half an inch in diameter, then ramming the mould full of a finely powdered mixture of two parts of coke and one of bituminous coal, and finally heating both the mould and its contents to redness for fifteen minutes. The bullet must be removed from the mould so soon as the latter has cooled, and excrescences being removed by a knife, it must be immediately plunged into the acid mixture just indicated. The piece of platinum wire serves to introduce it into J, an operation which must be performed with only momentary exposure of the fuming ball to the air, so as to avoid the access of atmospheric moisture, which would combine with the anhydrous acid and render it incapable of absorbing olefiant gas. The absorption of the olefiant gas takes considerably more time than that of the two first gases, and the ball must not be removed from the tube until an hour at least has elapsed. The residual gas is now contaminated with sulphurous acid and the vapour of anhydrous sulphuric acid, from both of which it is however at once freed by passing up into J two or three drops of concentrated potash solution. The residual gas being again measured in F as before the diminished pressure represents the volume of olefiant gas which has disappeared.

The remaining gas in the above list—carbonic oxide—is usually determined by the indirect method mentioned below, there are however certain cases in which its direct determination is desirable, although it is always less accurate than the indirect one. The direct determination of carbonic oxide is effected by absorption with solution of dichloride of copper; the latter is best prepared by allowing a concentrated solution of proto-chloride of copper to stand in contact with copper turnings in a closely-stopped bottle for several days. A quantity of this solution, equal in volume to about one-fourth of the carbonic oxide to be absorbed, must be passed up into J, and the gas being brought over from F must be left for five or ten minutes in contact with the solution, whilst a stream of mercury falls through it as in the two first determinations. The pressure of the gas being again measured, gives the volume of carbonic oxide absorbed.

The determination of any one of these gases in the absence of the others is effected in the same way, viz:

Carbonic acid by absorption with caustic potash;

Oxygen by a mixture of caustic potash in excess with pyrogallic acid;

Olefiant gas by anhydrous sulphuric acid; and

Carbonic oxide by dichloride of copper.

2.—*Indirect determinations.*

The following are the most important gases which are usually determined by the indirect method:—

Hydrogen.
Light carburetted hydrogen.
Carbonic Oxide.
Nitrogen.

The estimation of these gases even when all four are present in a mixture, is at once simple, expeditious, and accurate. It consists in exploding a known volume of the mixture in the tube F of the apparatus with an excess of oxygen, and then determining, 1st, the diminution of volume of the gaseous mixture after explosion; and 2nd, the volume of carbonic acid produced by the combustion. The residual gas remaining after absorption of carbonic acid consists of nitrogen mixed with the excess of oxygen previously added; the volume of the former is of course determined if we estimate that of the latter, which is effected by adding to the mixture of the two gases from two and a half to three times its volume of hydrogen, exploding in F and measuring the contraction produced exactly in the manner already described above for the analysis of atmospheric air.

The operations just described give us the following four data from which it is easy to determine the respective volumes of two or more of the four gases present in the mixture :—

1. The volume of the gas taken for analysis . . = A
2. The volume of the combustible gases present . . = A′
3. The contraction of volume on explosion . . . = C
4. The volume of carbonic acid generated on explosion = D

It will be seen that the value of A′ is ascertained by deducting from A the volume of nitrogen in the mixture, determined as just described.

The respective volumes of the three combustible gases are determined from the consideration of the contraction, and the volume of carbonic acid, produced by each on explosion, with excess of oxygen, as seen in the following table :—

Name of Gas.	Volume of Gas.	Contraction of volume on explosion with excess of oxygen.	Volume of carbonic acid produced by explosion with excess of oxygen.
Hydrogen . . .	1	1·5	0
Carbonic oxide . . .	1	0·5	1
Light carburetted hydrogen	1	2·0	1

If we now represent the volumes of nitrogen, hydrogen, carbonic oxide, and light carburetted hydrogen respectively by the letters w, x, y, and z, we have, taking the data just given, the following equations, expressing the volumes of the four gases present in the mixture submitted to analysis :—

$$w = \mathrm{A} - \mathrm{A}'$$

$$x = \mathrm{A}' - \mathrm{D}$$

$$y = \frac{3\mathrm{A}' - 2\mathrm{C} + \mathrm{D}}{3}$$

$$z = \frac{2\mathrm{D} - 3\mathrm{A}' + 2\mathrm{C}}{3}$$

If, on the application of these formulæ to the results of an analysis, the value of any letter be either a small negative quantity or = 0, it follows that the gas denoted by the letter is not present in the mixture.

The only difficulty likely to arise in making such indirect determinations, consists in adding neither too much nor too little oxygen to the combustible gas, since, when too much is added, either no explosion ensues on passing the electric spark, or, if the ignition of the mixture be effected, and light carburetted hydrogen or carbonic oxide be present, the temperature is too low to ensure the complete oxidation of these gases; whilst when too small an excess of oxygen is added, the violence of the explosion is so great as to endanger the rupture of the glass tube containing the gases. It is not difficult to avoid these contingencies where the nature of the gaseous mixture experimented upon is approximately known, if it be borne in mind that, of the three combustible gases above mentioned, each volume of hydrogen or carbonic oxide requires about 1¼ volumes, and each volume of light carburetted hydrogen about 5 volumes, of oxygen, for successful combustion.

We have thus given a very condensed account of this branch of chemical analysis; but for more minute details the reader is referred to the article 'Analyse fur Gase' (by the writer of the present article), in the 'Handwörterbuch der Chemie,' by Liebig, Poggendorf and Wöhler, 2te, Auflage. In conclusion, and as an illustration of the application of these analytical processes, we shall now describe the mode of performing an analysis of coal gas.

Analysis of Coal Gas.—Purified coal gas generally contains the whole of the following ingredients :—

1. Olefiant gas and analogous hydrocarbons.
2. Light carburetted hydrogen.
3. Hydrogen.
4. Carbonic oxide.
5. Carbonic acid.
6. Oxygen.
7. Nitrogen.

Of these ingredients, the first, fifth, and sixth are determined by the direct, and the rest by the indirect, methods above described.

Two or three cubic inches of the gas are passed into the tube J, and subsequently into F, for measurement. The oxygen, carbonic acid, and olefiant gas are now successively estimated in accordance with the methods described under the head of *Direct Determinations :* the mode of absorbing olefiant gas there given also effects the simultaneous removal of the analogous hydrocarbons, to which, in part, the diminution in volume will therefore be due. The remaining gas must now be exploded with about three times its volume of oxygen, and the respective volumes of the four remaining gases determined as described under *Indirect Determinations.*

This estimation of the relative quantities of the several constituents of coal gas does not give any absolute data from which the illuminating power and consequently the commercial value of coal gas can be calculated. It gives us, it is true, the amount of illuminating hydrocarbons (olefiant gas and analogous hydrocarbons) to which exclusively the illuminating power of coal gas is due; but as these vary in their light-giving powers in direct proportion to their richness in carbon, it follows that their value can only be estimated by determining the amount of carbon which a given volume of them contains. This can easily be effected by the additional operation of ascertaining the amount of carbonic acid generated by a given volume of the coal gas on explosion with oxygen, and comparing this with the amount produced on the explosion of the residual gas remaining after the abstraction of the hydrocarbons. For this purpose a known volume of the original gas is introduced into F (see *fig.* col. 320), and mixed with five times its bulk of oxygen; the electric spark is passed, and the volume of carbonic acid generated by the explosion ascertained by absorption with caustic potash in J. If we now denote the per-centage of hydrocarbons absorbed by anhydrous sulphuric acid by A, the volume of carbonic acid generated by 100 volumes of the original gas by B, the carbonic acid formed by the combustion of the non-luminous constituents remaining after the absorption of hydrocarbons from the above quantity of original gas by C, and the volume of carbonic acid generated by the combustion of the luminiferous hydrocarbons by x, we have the following equation :—

$$x = \mathrm{B} - \mathrm{C}$$

Consequently, the amount of carbonic acid generated by one volume of the hydrocarbons will be represented by

$$\frac{\mathrm{B} - \mathrm{C}}{\mathrm{A}}$$

Now, as the amount of carbon in each volume of the illuminating hydrocarbons is directly proportional to the volume of carbonic acid which these hydrocarbons produce on combustion, it follows that the formula just given expresses the illuminating power of the gas. For comparison, it is convenient to take as a standard the illuminating or carbon value of olefiant gas, which generates twice its own volume of carbonic acid. In order, therefore, to express the value of the luminiferous hydrocarbons of any sample of gas, in units of olefiant gas, it is only necessary to change the last expression into

$$\frac{\mathrm{B} - \mathrm{C}}{2\mathrm{A}}$$

Thus, any sample of gas containing 10 per cent. of hydrocarbons, of which one volume generates three volumes of carbonic acid, will have an illuminating effect equal to another gas containing 15 per cent. of olefiant gas. This method, therefore, furnishes us with an exact chemical standard of comparison for the illuminating value of every description of coal or other gas in use as a source of artificial light.

GAUGING is the method of determining by actual measurement the number of gallons contained in any vessel intended to hold goods. The greatest use of this art is in the collection of the revenue, in which it is necessary to measure the bulk of vessels without disturbing their contents. For this purpose a number of rules have been laid down by various writers, of whom the reader who is interested in the subject may consult Leadbetter's 'Treatise on Gauging,' John Ward's 'Young Mathematician's Guide,' or Dr. Hutton's 'Mensuration.' The rules laid down were, in many cases, of uncertain application; as, for instance, a close cask was to be treated either as a frustum of a spheroid, or of a parabolic spindle, or as a double frustum of a paraboloid, or else of a double cone, according to its appearance. The allowance made for the thickness of a cask was a guess, and the method of using *small* sliding-rules, to which supervisors formerly resorted to escape calculation, is a species of estimation which would never have been tolerated in money transactions between man and man. The inference to be drawn from the art as described by early writers, is that, generally speaking, the results of excisemen's measurements were below the truth: had it been otherwise, the fact could not but have been known to merchants and tradesmen, who can gauge their own vessels after the contents are removed, or who learn their bulk in the removal. If the methods of the excisemen were tolerably uniform, which is perhaps pretty nearly true, if we may judge from writers on the subject, no injustice was done by unequal taxation, and the government would probably have found it as easy to increase the duties, as to raise an additional revenue from a more correct method of collecting the old one.

With *larger* sliding-rules for calculation, and the aid of habit derived from experience, it is possible very accurately and easily to measure casks which do not depart much from a given standard of form. This is what is done by gaugers at the present time; and their practice has attained considerable accuracy. In a particular instance which has come to our knowledge, and in the case of a vat which held 6500 gallons, the measurement of the exciseman did not differ more than ten gallons from the truth. This degree of accuracy is entirely modern, and must in a considerable degree arise from similarity of form being very nearly preserved in the different species of casks.

The great variety of cases which occur would make a summary inconveniently long. Wherever a content is to be found, either the figure itself is simple and regular, as in the case of a cylinder, or nearly a simple figure, as in the case of some casks, which may be considered as the frusta of spheroids [see BARREL as an instance of the approximating supposition], or so irregular that the content can only be found by dividing them into a considerable number of sections, and considering each section as a small cylinder or frustum of a cone. [QUADRATURES, METHOD OF.]

The work on gauging which is most commonly used, is Symon's 'Practical Gauger,' which has been through several editions. Other works are, those of Leadbetter, Shirtcliffe, Moss, Gutteridge, and Iley. The first three are of the first half of the last century, and that of Shirtcliffe contains theoretical investigations. Ward's 'Mathematician's Guide,' and Hutton's and Bonnycastle's 'Mensuration,' contain small treatises on the subject.

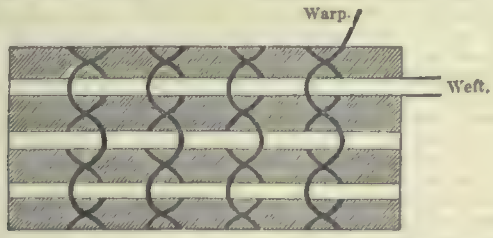
GAULS. [CELTÆ.]

GAULTHERIC ACID. [ESSENTIAL OILS. *Essential oil of Wintergreen.*]

GAULTHERILINE. [ESSENTIAL OILS. *Essential oil of Wintergreen.*]

GAUZE, a light transparent texture, made of fine silken threads. Its name has led to the conjecture that this fabric was first invented in Gaza, a city of Palestine. Spitalfields was, some years back, the principal seat of the silk-gauze manufacture in Great Britain; but of late Paisley and Glasgow, and the villages near those towns, have almost entirely engrossed this branch of husbandry; although some is made in the Derbyshire and Lancashire districts.

Gauze is one of the very few silken fabrics in the making of which the British manufacturer is still excelled by the French, both as to cheapness and quality. This cheapness results from the lower rate of wages paid to the French weavers as compared with ours; since the weight of silk contained in a yard of gauze is so trifling as to make the value of the material bear but a small proportion to that of the labour employed in its conversion.



The texture of gauze is different from that of plain weaving, in which the warp, or longitudinal threads, are always parallel to each other. The essential character of gauze-weaving is that between each cast of the shuttle a crossing of the warp threads shall ensue, and thus the weft (which forms the cross-threads interlaced by the warp) is not brought into absolute contact with the cross-thread immediately preceding. The intervals left between the interlacings cause that degree of transparency which, without such arrangement, could only result from a looseness of texture incompatible with beauty and utility.

In the present days of cheapness and imitation, gauzes, or textile fabrics receiving that name, are sometimes made of a mixture of silk and cotton; or even of cotton alone.

GAVELKIND, a customary tenure existing at this day in the county of Kent only. It seems that this tenure was the common socage tenure among the Anglo-Saxons (Glanvil, l. 7, c. 3), and the reason of its continuance in Kent has been ascribed to the resistance which the inhabitants of the county made to the Norman invaders. This tenure also prevailed in Wales until the 34th Henry VIII., when it was abolished by statute. The various derivations of the term Gavelkind which have been suggested are given in the 1st chapter of Robinson's 'Treatise on Gavelkind.' The distinguishing properties of this tenure are: "That upon the death of the owner without a will the land descends to all the sons in equal shares, and the issue of a deceased son, whether male or female, inherit his part; in default of sons, the land descends in equal shares to the daughters; in default of lineal heirs, the land goes to the brothers of the last holder; and in default of brothers, to their respective issue."

The tenant may alien at fifteen years of age, by means of a feoffment [FEOFFMENT], and the estate does not escheat in case of an attainder and execution, the maxim being, 'the father to the bough, the son to the plough.' The husband is tenant by curtesy of a moiety of his wife's lands, without having any issue by her; but if he marries again, not having issue, he forfeits his curtesy. A wife is endowed of a moiety of the lands of which her husband died seised, not for life as by the common law, but during chaste widowhood only. Gavelkind lands also were generally devisable by will before the statute of wills was passed.

Several statutes have been passed, at the request of holders of gavelkind lands, to render them descendible according to the course of the common law, or, as it is called, to disgavel them. These statutes, however, only alter the partible quality of the customary descent; they do not affect the other incidents to the tenure. And notwithstanding the extent of the disgavelling statutes, it is always presumed that lands in Kent are of this tenure, until the contrary is proved.

This tenure existed also in Ireland as an incident to the custom of tanistry—and as such ceased with that custom in consequence of the judgment against it. (Davis's 'Reports,' 28.) In the reign of Queen Anne, with the view of weakening the Roman Catholic interest in Ireland, the land of Roman Catholics was made descendible according to the custom of gavelkind, unless the heir conformed within a limited time; but by the stat. 17 & 18 Geo. III. c. 49 (Irish), the lands of Catholics are made descendible according to the course of the common law. (Robinson, p. 21.)

This customary descent is followed in some manors, particularly in the manors of Stepney and Hackney. (See the custumal of those manors printed in 2 Watkins, 'Copyh.,' 508.)

GAVOT (*Gavotta*, Ital., *Gavotte*, Fr.), a lively dance of two strains, in duple time. This generally followed the minuet, and still succeeds the *Menuet de la Cour*, when the latter is introduced on the stage.

GAZETTE (*gazzetta* in Itallan, *gaceta* in Spanish) is the name given to newspapers in several parts of the Continent. The name was, according to Ménage and others, derived from a small Italian coin, which was the price of the first newspaper established in that country. In England the 'London Gazette' is an official advertiser, printed under the authority of government, as are also the Gazettes of Edinburgh and Dublin for Scotland and Ireland. They contain all proclamations, orders in council, promotions and appointments to commissions in the army or navy, the nomination of sheriffs, the appointment of ambassadors, consuls, and other civil officers of the higher ranks, and all matters done by the queen in her political capacity; the production of the Gazette being sufficient evidence in courts of law for transactions in consequence thereof, except in some special cases, as to commissions, in which the Gazette is only secondary evidence when the production of the commission itself is refused. They contain also notices of all bankruptcies, insolvencies, and sequestrations, with other matters connected with proceedings under them; and the insertion of such notices is made a legal notice by special enactment; but in cases of dissolutions of partnership, special notice should also be given to parties with whom the firm has had dealings. Notices are required to be given in the Gazette during October and November (before the meeting of parliament), of intended applications for what are called Private Acts, relating to inclosures, canals, railways, and such matters. By special enactment also, it publishes the weekly and monthly returns of the Bank of England, and the bank-note circulation of all the banks in the United Kingdom, the prices of corn, &c.

Gazetteer has been used in England to mean a geographical dictionary, such as Brookes' 'General Gazetteer,' and other similar works.

GEARING. The parts of machinery by means of which the motion communicated to one principal portion of an engine is communicated to the rest, are known by the generic name of gearing, and they may be either multiplying, or retarding, fixed, or moveable, straight or bevilled gearing.

Multiplying or retarding gearing is that which is used for the purpose of augmenting, or diminishing, the velocity of the first motion, and its action in this respect depends upon the relative dimensions of the wheels gearing into one another. As the word *gearing* is no doubt derived from the German root *gerathen* "to fall, or come in, or into," it should, strictly speaking, be only applied to teethed wheels, but by extension it is frequently made to include also both band and friction wheels, and indeed in some cases their action is so nearly the same as that of teethed wheels, that it is hard to draw the distinction between them. The principles upon which the proportions of the diameters, and the number of teeth in multiplying or retarding gear, are fixed, in simple terms may be stated as follows. The velocities of wheels gearing into one another are in the direct ratio of their diameters; and they are also in the direct ratio of the number of the teeth. For instance, a wheel three feet diameter gearing into a wheel of only six inches in diameter, will travel with a velocity which will be only $\frac{1}{6}$ of that of the latter; and a wheel with 72 teeth will revolve in twice the time of the revolution of a wheel with 36 teeth. When eccentric, or occasional movements are required to be transmitted, it becomes necessary to employ either cams or eccentric gearing. [MACHINERY, COMPOSITION OF.]

Gearing is said to be *fixed*, when it is not susceptible of being disconnected with, or detached from, its corresponding work; as for instance when wheels are keyed upon their axles, and permanently placed upon the leading or following wheels to which they serve as intermediaries. *Moveable gearing* may be either loose upon a fixed axle, as in the case of the different parts of a mill wherein two shafts revolve above, or by the side of, one another, and are put in relative motion by means of a pinion gearing into fixed wheels on the two shafts, but able to be itself detached from them, either by being moved horizontally, or vertically by means of a lever; or it may be fixed upon its axle when the latter is susceptible of being put out of gearing by a lateral motion, as in the case of the various motion shafts of a crab. The clutch boxes, by means of which the respective portions of a long shafting are placed in connection with one another, come under the definition of moveable gearing; and like all other gearing of the same description, they may be so combined as to allow the direction of the motion to be changed at will.

Straight, or spur gearing is that which is employed when the axes of the respective wheels and axles are parallel to one another; *bevilled* *gearing* is that which is used when it is necessary to change the direction of the original motion, either angularly on the same plane, or at a different elevation, in a perpendicular or angular direction. Sometimes bevilled gearing is formed by cutting the teeth of the wheels upon portions of cones working into one another; or by means of teeth cut upon the path of a screw, working into a worm cut upon the upright shaft.

Perhaps it ought to be added, that the periods of revolution of the different kinds of gearing, whether fixed or moveable, straight or bevilled, are quite as often equal, or synchronous, as they are slower or faster. When the periods of revolution are synchronous, the wheels are, of course, of equal diameters.

GEIC ACID. [GEIN.]

GEIN, a name given to *humus* in common with *ulmin*, *humic acid*, *ulmic acid*, *humin*, and *geic acid*. This substance is obtained from common mould, which when boiled with alkalies, and the solution filtered and treated with acids, yields a brown deposit, which has the above names. Mülder states that the substance contains 2½ to 7 per cent. of nitrogen. These substances appear to be vegetable matters in a state of decay.

The name *gein* has also been given to a bitter non-azotised matter found in the root of the *Geum urbanum*. Its composition is not known.

GELATIN. The physiological relations of gelatin, and its value as an article of food, have already been described. [GELATIN, in NAT. HIST. DIV.] The present article will, therefore, merely contain a description of its manufacture for commerce, and the chemical action of various substances upon it.

Parings of the hoofs and horns, the crushed bones, and the cuttings of the hides of animals, are placed in cast-iron cylinders, and subjected to the action of steam at ordinary or at a more or less increased pressure; a strong solution of gelatin in hot water is thus produced, which is poured out on to polished slabs of tin, marble, &c., to solidify, and the resulting sheets afterwards cut into shreds by machinery. If the gelatin is required for dietetic purposes, great care is observed in the selection and cleaning of the materials from which it is to be obtained. Some makers bleach it with sulphurous acid, flavour it with various essences, well dry and powder it to render it more rapidly soluble in water, and one patentee even takes the trouble to dry it in vacuo. Gelatin of a common description is used in pharmacy for making *capsules*, little bags intended to contain active medicinal preparations of nauseous taste and odour; also for coating pills. Sheet gelatin, coloured, is now largely used as an ornamental envelope for confectionary, &c., and in the fabrication of toys and other small articles.

Gelatin softens and swells up in cold water, but does not dissolve. It is also insoluble in alcohol, ether, and the fixed and essential oils. Boiling water dissolves it in considerable quantity. If a sheet of tolerably soft gelatin be printed upon, and then immersed in spirit of wine, a considerable but equal contraction takes place; and the print transferred to stone furnishes impressions similar to the original, but much reduced in size. By printing upon a sheet of very dry gelatin, and afterwards immersing in water, the converse of the above result is obtained.

Chlorine acts upon gelatin, forming with it a white compound, from which the gelatin may be reproduced unchanged on the addition of ammonia. Nitric acid converts gelatin into oxalic acid, and other products. Sulphuric acid transforms it into leucin, a kind of sugar called glycocin, and into some other products. Acetic acid dissolves gelatin; strong alkalies decompose it. Its aqueous solution is precipitated by bichloride of platinum, corrosive sublimate, infusion of galls, or any liquid containing tannin, but is not rendered even turbid by solution of ferrocyanide of potassium, a test by which gelatin is at once distinguished from albumen.

From the difficulty of obtaining gelatin in an absolutely definite condition, its true chemical composition is somewhat uncertain. The formula usually adopted for it is $C_{13}H_{10}N_2O_5$; this nearly agrees with the following per centage results obtained by Mülder :—

Carbon	50·40
Hydrogen	6·64
Nitrogen	18·34
Oxygen (including trace of sulphur)	24·62
	100·00

GELATINE AND GLUE. These nearly-allied substances may conveniently be noticed together, in relation to their manufacture and uses.

Gelatine.—Gelatine is used partly as an agent in food, and partly as a cement. Much of it exists in the bones of animals; and it affords one evidence of the improved processes of modern times, that so valuable a substance is now saved which used formerly to be wasted. The jelly can be obtained by the action of heat on the organised tissue of bones, tendons, ligaments, sinews, skin, and serous membrane, whilst in contact with water. Isinglass is nothing more than a purer kind of gelatine. All gelatines dissolve more or less in hot water, and form a translucent jelly. Gelatine and tannin form leather, a fact which explains the rationale of the tanning process.

Without touching in this article on the chemistry of gelatine as an article of food, we may mention that gelatine is nourishing as a diet, but not alone; for it is wanting in flesh-making elements. The late Sir Samuel Bentham, a person of great ingenuity, drew the attention of the Admiralty, in 1829, to the advantage and economy of supplying the navy with gelatine procured from bones, by a process invented by D'Arcet long before, and much practised in France. French workmen, and some of the inmates of French hospitals, are frequently supplied with soup made from bone-gelatine at a cost of one farthing per pint; and it could be made sufficiently strong to be portable when cold for one halfpenny. Bentham proposed that the bones of salt beef should not be thrown away, as at present, on shipboard. If the joints were deprived of the bone before the meat is shipped, the good beef could be packed in a small space, and thereby economise stowage on board; while the bones would be available as a source of gelatine. Beef bones contain 30 per cent. of gelatine, and 10 per cent. of fat, which can be extracted by processes easily managed. The gelatine could be flavoured and dried, and would be very valuable as an article of ship diet. The meat also could be more easily and perfectly salted, and could be rolled up like Hamburg beef before being put into the casks. Bentham, calculating on the basis furnished by the French chemists, asserted that the bones which are stripped of their meat every day in London, would furnish gelatine sufficient for one small basin of soup to every one of the inhabitants, young and old. He impressed his views on the Admiralty, but without success; and we believe bone-gelatine does not yet form an element in the dietary of the British navy. The French adopt the system much more extensively than ourselves. On the large scale, the gelatine is extracted by steam, and sometimes a little muriatic acid is employed to remove the phosphate of lime. Even *fossil* bones have been made to yield gelatine.

The power of obtaining gelatine from bones being once understood, the variety of applications becomes very considerable. Bone-gelatine, for divers purposes, is bleached with sulphuric acid or animal charcoal. It may be tinted blue by sulphate of indigo or juice of blue-berries; green, by the juice of spinach; or red by that of beetroot. Cake gelatine is made by the French from the cuttings of the skins used in kid-glove making. Nelson's patent gelatine is obtained from glue-pieces or cuttings from the hides and skins of animals. In preparing it, the fragments are freed from hair, wool, flesh, and fat; then steeped for several hours in a solution of caustic soda; then placed in covered vessels at a temperature of 60° or 70° Fahr.; next washed to expel the alkali; then exposed to the vapours of burning sulphur; and then dissolved in water at a temperature of 150° Fahr. After this, the solution is strained into settling vessels, where it is kept for several hours at a temperature of 110° Fahr. It is then poured to the depth of half an inch upon a cooling slab, and the resultant cake of jelly, after a few further processes, is prepared into one of two kinds, opaque or transparent—both intended as substitutes for isinglass. Rattray's patent gelatine is another kind, produced in a somewhat similar way from waste glove-pieces. Swinburne's patent gelatine is made from the cuttings of calves' skins. What is called *rough* gelatine is made from the spongy insides of the horns and ribs of oxen, and the softer parts of the skulls and other bones, also from sheep's bones—the preparation requiring, of course, a good deal of cleaning, steeping, boiling, steaming, evaporating, &c.

Glue. This thicker kind of gelatine is prepared from the clippings of hides, hoofs, &c., obtained at the tan-yard. The first operation is to wash this refuse in lime-water, and afterwards to boil it in water, and skim the solution, which is then rendered clear by being strained through baskets, and evaporated by a gentle heat to a proper degree of thickness. It is finally cooled in wooden vessels, cut into thin portions, and dried upon coarse net-work. When properly prepared, glue is of a deep brown colour, translucent, and free from spots and clouds. When required for use, it is broken into pieces, and steeped for about twenty-four hours in cold water, by which it swells and softens. When gently heated in a water-bath, such as the common glue-pot is, it is applied by means of a brush to the various kinds of work for which it is used. The adhesion depends upon the evaporation of the water. Mr. Tucker patented a process, in 1856, for drying glue without the use of a netting. He pours the boiled mass into separate pans disposed on racks in a drying chamber; heat is applied at a temperature of 140° or 150° Fahr., and fans are then rotated to send a current of air through the chamber. Another proposal for drying is to pass the glue into a vessel fitted with a horizontal metal cylinder, kept heated by steam within or by a steam jacket on the outside; the lower half of the cylinder dips into the glue, and revolves at a slow rate, the surface takes up a thin film of the glue, which quickly solidifies and dries; a film is thus formed and dried at each revolution of the cylinders.

Besides the application of gelatine to food, and that of glue as a cement, both are used in very numerous ways in the mechanical arts. Glue and treacle make a peculiar elastic substance very useful for printers' inking-rollers. Gelatine casts, and gelatine moulds for casts, are now very common—especially the latter, on account of the ease with which the casts can be taken out of them. The *gelatineurs* of Paris make sheets of exquisitely fine gelatine, dyed to the most brilliant colours. These sheets can be applied to many useful purposes; they can be used as a layer on the surface of an engraving or woven material to which it will serve as a varnish; they can be made into a substitute for carton, for address and visiting cards; they can be employed by wood engravers in transferring or copying designs; and when made extremely thin, they can be used as wrappers and envelopes for fancy articles, as materials for transparent artificial flowers, and as a substitute for paper on which printing in gold may be effected.

The *size* used by paper hangers, white-washers, &c. is a kind of thin glue made from parchment cuttings. Jeffery's *marine glue*, an uncommonly powerful cement used in shipbuilding, is not properly a glue at all; it is a combination of other substances than gelatine.

GE'MINI (the twins), the third constellation in the Zodiac. The Greeks refer it not only to the fable of Castor and Pollux, but also to those of Hercules and Apollo, Triptolemus and Iasion, Amphion and Zethus, &c.

The principal stars are as follows:—

Character.	No. in Catalogue of Flamsteed.	No. in Catalogue of British Association.	Magnitude.
μ	13	2047	3
γ	24	2163	2·5
ε	27	2194	3
θ	34	2237	4
α	66	2485	1

This constellation derives its name from two remarkable stars, of the first and second magnitude, to which the names of Castor (or α Geminorum) and Pollux (or β Geminorum) are given. The latter star is marked by Flamsteed as of the first magnitude, by the greater part of astronomers as of the second, and by Piazzi as of the third! These two stars, whose proximity will cause them to be easily recognised when once known, may be found by drawing a line through the belt of Orion and the two bright stars the line of which cuts through the belt. This line, lengthened upwards, will pass very near to the two stars of Gemini. They are also about halfway between Regulus and Aldebaran: and if the Great Bear and Orion be seen together, then Capella on the one side, and Castor and Pollux on the other, will be conspicuous boundaries of the intermediate space.

GEMS. [CAMEO; INTAGLIO.]

GEMS, ARTIFICIAL. [GLASS.]

GENDARMERIE (from *Gens d'Armes*, men-at-arms) was a chosen corps of cavalry under the old monarchy of France: it is mentioned with praise in the wars of Louis XIII. and Louis XIV. Under the present system the gendarmerie is a body of soldiers entrusted with the police all over France; it furnishes patrols, arrests criminals, examines the passports of travellers, and contributes to the maintenance of good order. Gendarmes are generally stationed at the barriers or gates of the towns, at the principal inns on the roads, at markets and fairs, and along the lines of the frontiers. They are divided into foot and horse: *gendarmes à pied*, *gendarmes à cheval*. They form a distinct corps in the army, under their own superior officers, who are under the orders of the ministers of the interior and of police; but in case of war, they may be called into active service like the other corps of the army. The gendarmerie is mostly recruited from old and deserving soldiers of other regiments, who consider it as a promotion, as they have better pay and enjoy greater liberty. This explains why the gendarmes, generally speaking, are remarkably well behaved and trusty men, who, while strictly executing their duties, behave with considerable civility towards unoffending people, such as travellers, and especially foreigners. The same description of troops exists in the Italian states, where they are called Carabineers.

GENDER is a grammatical principle entering into the structure of many languages, according to which nouns are distributed into classes. There are, strictly speaking, but two genders, *masculine* and *feminine*; those which belong to neither of those classes were said to be *neutrius generis*, of neither gender: this third class are called somewhat incorrectly *neuters*, and hence by a second irregularity it is the ordinary practice of grammarians to speak of three genders.

That sexual distinction was the fountain from whence the doctrine of grammatical gender was derived cannot be reasonably disputed. As a consequence of this the principle must have been confined originally to living beings, and among these it must have been still further limited to those animals where the distinction of the sex was readily perceived, as in the mane of the lion, the plumage of the peacock, or the magnitude of the bull. In the smaller animals it would be often difficult to ascertain the sex, and useless to denote it. But utility and truth are not the sole governing principles of language; they are often sacrificed to the love of imagery and personification. Thus the beautiful and pleasing absurdity which characterises the language of fable recommends itself to the infant mind whether of the savage or the child. The rose, the lily, the sun, the moon, are all endowed with the faculty of speech, and it then becomes almost necessary to add the distinction of sex. Here the choice must depend upon the association of ideas. Action, freedom, strength, magnitude, and violence, are the marked attributes of the male; sufferance, subjection, timidity, together with pregnancy, of the female. In the application of these notions, the realities of nature are often neglected. The domestic animals, having lost all the violence of the natural state, convey to the mind the idea of something feminine. Thus among the Romans even the dog was in ordinary language considered to be of that gender, perhaps because it was inferior in power to the wild wolf; while the English, contrasting that noble and powerful animal with the clean and delicate but irritable cat, have allotted the masculine gender to the dog, to the other the feminine. The feathered creation again, by their small size, their weakness, and the delicacy of their plumage, are naturally associated with the tender sex, with the exception commonly of the eagle, kite, hawk, &c.

In the meanwhile the neuter is employed to denote that the notion of gender is not entertained; it is therefore, as Grimm has well observed, the proper grammatical form for the young of animals, where the sexual distinctions are imperfectly developed. Thus in the greater part of the Teutonic languages, the terms for *foal*, *calf*, *lamb*, *child*, &c., are of the neuter gender; and in the Greek there occur many similar forms, as τεκνον, βρεφος, &c. Hence, by an easy connection the diminutives generally in the Greek and Teutonic languages are of the same gender; and this principle is carried to such an extent that a neuter diminutival suffix is at times employed in the formation of the names of women, as *Dorcium*, *Glycerium*, in Terence, *mägdchen*, *Gretchen*, "little Margaret" in German. In the further extension of the idea of gender, first to material objects without life, and then to abstract terms and mental notions, the directing associations are weaker, and the mind is in a state of oscillation. It may be observed, however, that abstract nouns, or to speak more correctly, general terms, are usually included among the feminines, perhaps from a notion of pregnancy, the one term including a large aggregate of concrete ideas. There are indeed exceptions to this principle; for instance, in the large family of Latin words which have the suffix *or* (*honor*, *pudor*, &c.), but this variety is probably to be explained by the similarity of the termination to the masculine suffix *tor*. The French language has corrected this anomaly in *la pudeur*, &c. We have here probably an explanation of the principle by which in Greek a feminine article attached to what is commonly a masculine substantive gives it the power of a collective, as ιππος, m. "a horse," but ἡ ιππος, "the horse," that is "the cavalry;" ἡ καμηλος, "the body of camels." The same peculiarity belongs to the Arabic and Hebrew, and indeed is still preserved in a modern Semitic language, the Galla.

The mode of denoting gender is also deserving of consideration. One of the most direct methods would appear to be to assign names absolutely different to the male and female, that is, in those cases where the terms are used in their natural, not in their metaphorical sense. Thus we have in our own language *boy* and *girl*, *horse* and *mare*, *bull* and *cow*, &c. One of the defects of such a principle would be the want of a general rule by which to denote the gender in any new instance, and the consequent multiplication of terms. But independently of the advantages and disadvantages of this notation, there are good reasons for believing that in fact the distinction of sex was not originally denoted by an absolute difference of term. The word *man* for instance, in the oldest Teutonic language had the general meaning of a human being, like the Greek ανθρωπος, or Latin *homo*, and only gained the exclusive notion of a male when its derivative *mannisco* or *mensche* was formed to express the general idea. The German term *frau* again is now confined to the female, but there is found in nearly all the older dialects of the German a masculine so nearly identical (*frauha*, Gothic; *frô*, old high German; *froho*, old Saxon; *frea*, Anglo-Saxon) that the notion of the female can scarcely have been inherent in the word. Similar results would be given by an examination of the English word *maid*, the Latin *puer*, &c. In the animal kingdom the same confusion prevails. The Latin *ovis* is commonly feminine; and in fact our English term *ewe* may be indisputably proved to be the same word; still, in the earlier form of the Latin language, the word was also applied in the sense of *aries*. It occurs, for instance, in the name of the sacrifice *Suovetaurilia*, where the word *taurus* leads us to expect the idea of a *ram* in *ovis*, and of a boar in *sus*; and in fact ancient reliefs prove that the animals sacrificed at this festival were uncastrated males. The word *sus*, corresponding in ordinary signification, as also in form, to the English *sow*, is a parallel case. Indeed both Greek and Latin exhibit this very word as not confined to either sex. A long enumeration of similar instances, with the necessary proofs, would be out of place here. It will be sufficient to notice that the English terms *mare* and *hen* appear in other branches of the Teutonic language as representatives of the male. Lastly, those who attribute to these monosyllabic forms a distinct notion of gender will find it difficult to avoid the inference that if *gallus* for example, originally meant a *cock*, and not as is here maintained, a *fowl* generally, *gallina* included the notion of both sexes, a *female cock*. A more simple mode of denoting gender is by the addition of a special suffix. Thus the Latin termination *on*, like the Italian *one*, appears to have carried with it the idea of a man, as in the familiar cognomina *Nason*, *Capiton*, &c. Thus again, *leon*, "a lion," is in reality formed of two words, *le* or *li*, the simple name of the animal, and *on*, man or male. The form *li* (nom. λις) occurs in the Greek language as well as λεων; and moreover, if the name of the animal was thus monosyllabic, it is seen at once how natural it was to adopt it, as was in fact the case, for the hieroglyphical symbol, or at any rate for the Hebrew character of the letter *l*. The addition of the feminine suffix *ina* or *aina* to the same root *le* gave the female, *leaena*; and indeed the same suffix appears in *gallina*, *regina*, the Greek βασιλιννα, the German *königinn*, &c. Of the male suffix, other examples may be seen in *centurion-*, *caupon-*, *falcon-*, *pavon-*, &c.; the last of which may be compared with the Greek *ταω-ς*, and the English *pea-cock*. The most frequent suffix in the Greek language to denote the feminine is the syllable *σα*, as in *Φοινισσα*, *κιλισσα*, and the participles *τυπτοντσα*, the parent of *τυπτουσα*, *τυφθεντσα*, afterwards *τυφθεισα*. The same suffix is found in the Gothic, as *gaitsa*, *capra*; and in German, as *farre*, a bull, *färse*, a cow. Our own language too is familiar with what is probably the same suffix in *seamstr-ess*, *laundr-ess* (from *lavender-ess*). In the Greek language this suffix appears at times to have lost its sibilant, as was so common in that language. Hence the forms *βασιλε-ια*, *αξε-ια*, *τετυφυ-ια*, for *τετυφοτ-ια*.

In the Latin language a mere vowel *a*, but originally a long *a*, as is proved by the Sanscrit, by the oblique cases of the Latin first declension, and in old Latin even by the nominative, for the forms *aquilā*, *sanctā filiā*, &c., occur in the earliest poets, while the Greek too has not a few nominatives with a long *α*. But the forms *scriba*, *incola*, &c., with the numerous proper names, *Cinna*, *Sulla*, &c., prove that the notion of the female was not inherent in this declension; and probably the fact was that there co-existed in primeval Indo-European language two dialects, one preferring *a*, the other *o* (precisely as in our own island, there are the two forms *two* and *twa*, *who* and *wha*, *one* and *ane*); and secondly, that by a false refinement in language, an arbitrary distinction of gender was set up between them. The same argument of course applies to the Greek form *αγαθο-ς* and *αγαθα* or *αγαθη*, in which it must be carefully recollected that the sibilant at the end of *αγαθος* has nothing to do with the question, as it is simply the representative of the nominative case. It should also be recollected that the older Greek language abounds in the common adjectives, such as *ὁ* and *ἡ αθανατος*. Moreover the advocates of an original distinction of gender in the two first declensions have to explain the anomalies of *ἡ ὁδος*, &c., and the Latin *fagus*, &c. Again, that the Latin forms *bono-* and *bona-* were originally but dialectic varieties appears to be established by the consideration that nearly all derivatives from the second declension take an *a*, as *albare*, *aurare*, &c., a strange consequence of which is, that the Latin language is almost wholly deprived of a conjugation of verbs in *e* corresponding to the Greek *δουλε-ω*. It is another strange fact, that in Gothic the forms in *a* are masculine, those in *o* feminine.

Lastly, every language has the power of denoting gender by the addition of a distinct word, as in *jack-snipe*, *cock-sparrow*, *tom-cat*. This use of the names of men is seen in other languages besides our own. Thus the Anglo-Saxon employs *carl* for this purpose. In the German *täuberich gänserich*, it would be wrong, however tempting, to asume that the past *erich* is the prenomen; we should rather divide the words so as to give to *er* the notion of a male, and to *ich* that of a diminutive. Thus *täub-er-ich* is the "little-male-dove." Violent corruptions of this form exist in our tongue in *lark*, abbreviated from *laverock*, a term still used in Scotland; and *drake* from *andrake*, itself a corruption from *anat-er-ock*.

The suffix *ster* of our own language marks a female agent, and still preserves the sense in *spinster*. The words *bagster*, *webster*, *brewster*, refer to offices not ill-suited to the female, but they have now disappeared as appellatives, and are employed, in England at least, solely as surnames. The male terms which correspond to them are of course *baker*, *weaver*, *brewer*. It is in the Dutch that the best evidence exists to show that *ster* is truly a suffix to denote female agents.

Nothing has been said of suffixes to denote the neuter gender; simply because there exist, strictly speaking, no such suffixes. There are indeed appearances of such additions; first, in the Greek neuters *αγαθον*, and the Latin *bonum*; secondly, in the neuter pronouns of the Latin language terminating with a *d*, which correspond to an *s* in German and a *t* in English; as *quod*, *was*, *what*; *id*, *es*, *it*, &c. Of the first class it is enough perhaps to throw out a suspicion that the *m* and *d* (*s*, *t*) were originally part of the stem of the noun, and no case-ending.

In the Scandinavian languages, as now existing, the genders have a peculiar character, consisting of a neuter, if gender it can be called, and a common gender, which includes the masculine and feminine. By a strange accident, the definite and indefinite articles have here a common form, and are distinguished solely by their position. Thus the word *one* or *an*, as written by us, is represented by *en* m. or f., *et* n.; while the definite article, of the same form, but no way related to it, is attached as an enclitic. Thus we have in Danish for the common gender: *en mand*, "a man," *manden*, "the man;" *en quinde*, "a woman," *quinden*, "the woman," *en dag*, "a day," *dagen*, "the day;" and for the neuter, *et lam*, "a lamb," *lammet*, "the lamb;" *et ord*, "a word," *ordet*, "the word." The *en et* of the definite article may be compared with the forms *εν* of *εν-θεν*, *in* of the Latin *in-de*, and our own *it*.

GENEALOGY. [PEDIGREE.]

GE'NERA, in ancient Greek music, were of three kinds,—the Diatonic, Chromatic, and Enharmonic. [DIATONIC; CHROMATIC; ENHARMONIC.] These were subdivided into many species, which are enumerated by Gaudentius and Aristoxenus. "Indeed," says Sir J. Hawkins, "the representations of the genera and their species, as well by diagrams as in words, are almost as numerous as the writers on music." To that erudite historian of music we refer the reader who wishes for more information on a subject in which so few now take the slightest interest. The modern diatonic and chromatic genera, or scales, are probably much the same as, or nearly allied to, those of antiquity. Our Enharmonic is, practically,—at least on most instruments,—but a convenient evasion, the mere bestowal of two names on one and the same sound.

GENERAL, the title of the highest tank conferred on military officers. In all the states of Europe it indicates the commander-in-chief of the forces of the nation; the commander of an army or grand division, and also those who, under the latter, exercise his functions, with the particular designations of lieutenant general and major-general.

The origin of the title appears in the history of France, in which country it seems to have been conferred on the commander of the royal army about the middle of the 15th century, when something like a regular military force was first established in Europe. The kings were then considered as holding the chief command of the army by virtue of their birth; and, on appointing persons under them to exercise a general superintendence of the forces, they gave to such officers the title of *lieutenant-general*, in order to designate at the same time the extent of their duties and their dependence on the sovereign whom they represented. By a decree made in the year 1450, in the reign of Charles VII., John, count of Dunois, was so qualified; and the title of lieutenant-general, denoting the immediate commander-in-chief of an army, was long retained in the French service. In the course of time, by an abbreviation in language, the prefix of the title was omitted, and the term *general* alone was applied to persons holding such command.

Previously to the epoch above mentioned the title of Grand Sénéchal of France appears to have conferred the right of commanding the royal armies; but the dignity being hereditary in the counts of Anjou, when that province passed to the crown of England in the reign of Henry II., the right ceased, and the kings of France delegated their authority to noblemen chosen at pleasure. In 1218 Philip Augustus conferred the command on Mathieu de Montmorenci, the Constable of France; and the successors of that high office held it till the re-formation of the army in the reign of Charles VII.

It must be remarked, however, that at a period more early than that of the creation of lieutenant-generals under the sovereign, the title of captain-general had been conferred on certain officers with military jurisdiction over particular districts. This species of command is supposed to have been first instituted in 1349 by Philip of Valois, who placed Guy de Nêle, already Maréchal de France, over the district of Xaintonge; within which he was authorised to inspect the castles and fortified towns, and to superintend all the military affairs. The nature of the duty therefore seems to have resembled that of the general officers now appointed to particular divisions of this country and the colonies. But in 1635, that is, about eight years after the suppression of the post of constable of France, Louis XIII. gave the title of captain-general, for the army of Italy, to the Duke of Savoy; and this appointment was precisely that of commander-in-chief, since it placed the duke above the Maréchal de Créqui, who was previously at the head of the army.

It is about this time that the term lieutenant-general, in the sense which it now bears, first appears. For, according to Père Daniel, who quotes the history of Cardinal Richelieu for the fact, when the Prince of Condé was made commander-in-chief of the army destined against Spain, the Marquis de la Force was appointed his *lieutenant-general*, and M. de Feuquères held the same rank under the Duc de Longueville, who was to act with an army in Franche-Compté. We have here but one lieutenant-general for each army: but the writer above mentioned observes that, during the reign of Louis XIV., the armies of France being much more numerous than before, the officers were also greatly multiplied; and adds that, in 1704, there were more than sixty who had the title of lieutenant-general.

The title of captain general above mentioned must not be confounded with that which was created by Cardinal Richelieu, in 1656, in favour of the Marquis de Castelnaut: this officer was placed above the lieutenant-generals of the army, but was subordinate to the marshal of France, who commanded in chief; and it appears that some of the former having retired from the service in disgust, in consequence of the new appointment, the cardinal was obliged to appoint others in their places.

In the reign of Francis I. the title of colonel-general was instituted; and it was first in 1544 conferred on M. de Taix, with the command of all the infantry of the nation. The title existed however only to the time of Louis XIV., by whom it was abolished.

The English nation has nearly followed the practice of France in matters appertaining to the military service. Thus the lord high-constable and the lord-marshal of England, in former times, were at the head of the military establishments of the country; and when the first office was suppressed by Henry VIII. in 1521, the title of captain-general appears to have been adopted for the commander-in-chief. This title occurs in the list of the army which served at St. Quintin in 1557, of which list a copy is given by Grose from a MS. in the British Museum. From the same list it appears that a lieutenant-general for the whole army was immediately subordinate to the former; and that under the last was a general of horse, a captain-general of foot, with his lieutenant, and a serjeant-major (corresponding to a present major-general). But the title of captain-general probably did not long remain in use; for, in the list of the army raised by Elizabeth in 1588, the highest officer is styled lieutenant-general, the queen herself being probably considered as the commander-in-chief. In the army which, in 1620, it was proposed to raise for the recovery of the Palatinate, and in that raised by Charles I. in 1639, the commander is entitled the lord-general; a lieutenant-general appears as the second in command, and the third is designated sergeant-major-general. It was probably soon after this time that the last officer was called simply major-general; for we find that in 1656 Cromwell appointed twelve officers under that title to have civil and military jurisdiction over the counties of England. (Clarendon, b. 15).

It is evident, from the histories of the northern states, that the armies in that part of Europe have always been commanded nearly in the same manner as those of France and England. Sir James Turner, who wrote his 'Military Essayes' in 1670, states that in Germany, Denmark, and Sweden, the commander-in-chief was designated field-marshal, and that he had under him lieutenant-generals of the whole army, besides generals and major-generals of horse and foot. With respect to the first title, he considers it to have been granted, as a more honourable distinction than that of lieutenant-general, only within about fifty years from his time: and he appears to ascribe the introduction of it to the king of Sweden (Gustavus Adolphus), who, when he invaded Poland, thought fit to gratify some of his generals by designating them lieutenant-field-marshals. ('Pallas Armata,' ch. 13.) From that time, both in Germany and Great Britain, such title, omitting the word lieutenant, has been considered the highest in the army.

In France, during the reign of Louis XIV., and perhaps at an earlier time, the naval commander immediately below the rank of vice-admiral was entitled lieutenant-general. A similar designation seems to have been early employed in the English service, for in the time of Queen Elizabeth the commander of a squadron was called the *general;* and, as late as the time of the Commonwealth, a joint commission of admiral and general was given to Blake and Montague, though the expedition on which the fleet was sent was confined to an object purely naval.

The administration of military affairs in the great nations of Europe becoming highly complicated during the eighteenth century, the commanders-in-chief, even when not actually on the field of battle, found themselves fully occupied with the higher departments of the service; and it became indispensable that the number of subordinate generals should be increased, in order that all the steps which were to be taken for the immediate security of the armies, and for the acquisition of the necessary supplies, might be duly superintended by responsible officers. The division of an army into brigades and divisions for the purpose of organisation and also of occupying important positions or of obtaining subsistence, led also to the appointment of several distinct commanders, each of whom required his own particular staff; and this circumstance, added to the necessity of having a number of officers prepared at once to assume the command of troops when circumstances should require it, will explain why military men holding the rank of general appear now to be so numerous.

In the British service there are about 60 full generals, and 100 lieutenant- and 160 major-generals; of this number many command particular regiments as colonels, or hold military governments in the country and colonies; many of them have only local rank; and many have retired from the service, retaining the title, but without receiving the pay or being qualified for obtaining any progressive promotion.

The adjutant- and quarter-master-general are officers of the staff. [STAFF.]

In the English army, a general of division is either a major or lieutenant-general placed in command of a division of an army in the field, and a brigadier-general is either a colonel or major-general in command of a brigade—the titles only lasting while the officer is actually holding the command. In the French service however, general de brigade and general de division are permanent ranks answering to our major-general and lieutenant-general.

The first notice of a commander of the artillery occurs in the time of Richard III.: this officer was designated simply master of the ordnance till 1603, when the Earl of Devon was dignified with the title of General. The head of this department was, till lately, styled master general of the ordnance. The office is now abolished.

GENERAL ASSEMBLY OF THE CHURCH OF SCOTLAND. This is the Scottish ecclesiastical parliament; it is a representative, legislative, and judicial body, which differs essentially in its constitution from the Convocation of the English church [CONVOCATION], in being composed of representatives of the laity, as well as of the clergy; and, therefore (like the British House of Commons), may be considered as a delegation from its constituency, the church. [CHURCH.]

The General Assembly consists of representatives from the various presbyteries, of which there are 84; of lay elders sent from Edinburgh and many other royal burghs, and from the universities (the representatives of the universities may be either ministers or elders);—and one minister and one elder to represent the churches in India in connection with the church of Scotland. The kirk of Scotland in 1859 had 1023 parishes, with 1194 ministers.

The General Assembly meets annually, in the month of May, in Edinburgh. The session lasts only ten days; but special business not decided within the period of the session may be referred to a commission, which is, in fact, the Assembly under another name: the commission can hold quarterly meetings. The speaker, or president of the assembly, is called moderator: he is chosen annually, and is, in modern times, a clergyman, it being a rule that the moderator should preach a sermon before the opening of the Assembly; but laymen have occasionally filled the chair.

Each parish in Scotland has its kirk session, composed of the minister and lay elders of the parish, which manages the parochial business. From the decision of the kirk session there is an appeal to the presbytery in which the parish lies. Each presbytery is composed of the ministers and elders of a certain number of parishes; but the presbyteries vary considerably in the number of parishes of which they are formed. A higher court, called a synod, (of these there are sixteen) is composed of two or more presbyteries. From the decision of a synod an appeal lies to the General Assembly, whose decision is final. The functions of the Assembly are analogous to a combination of the functions of both houses of parliament. Its members speak and vote; it judges all matters connected with the government of the church; and it can proceed judicially against any member of the church, clerical or laical, for alleged impropriety or inconsistency of conduct or doctrine.

The connection of the Church of Scotland with the State is indicated in the General Assembly by the presence of a functionary, who, under the title of lord-high-commissioner, represents the king or queen. The Scottish church however does not recognise the king or queen as head of the church, but as head of the state, with which the church is allied, for purposes of protection and civil authority. The lord-high-commissioner has no voice in the assembly; business is not necessarily interrupted by his absence; and his presence merely implies the sanction of the civil authority. On the conclusion of the session of the General Assembly, the moderator, after mentioning the day in the following year on which the Assembly meets again, dissolves the meeting in the name of the Lord Jesus Christ, the head of the church (sometimes the words 'the only head' are used), and then the lord-high-commissioner adds the sanction of the civil authority by appointing in the name of the king or queen the Assembly to meet on the day named by the moderator.

The Free Church, since the disruption, has held a General Assembly of its own, about the same time as that of the established Church, but it is not recognised by the government more than the assemblies of other sects for the internal management of their own ecclesiastical affairs.

GENERAL ISSUE. [PLEADING.]

GENERALISSIMO, the commander-in-chief of an army which consists of two or more grand divisions under separate commanders. The title is said by Balzac to have been first assumed by Cardinal Richelieu, when he led a French army into Italy, and it has been since occasionally given to officers at the head of armies on the continent, but it has never been adopted in this country.

GE'NERATING FUNCTIONS. The term *generating function* is a name given by Laplace to any function of x, considered with reference to the coefficients of its expansion in powers of x, as follows: If

$$\phi x = \psi 0 + \psi 1 \,.\, x + \psi 2 \,.\, x^2 + \ldots + \psi n \,.\, x^n + \ldots.$$

then ϕx is the generating function of ψn. Thus, the generating function of n is $x \div (1-x)^2$, since the coefficient of x^n in the expansion of the preceding is n.

The theory of generating functions was investigated by Laplace, and it may be found in his 'Théorie des Probabilités,' or in Lacroix, 'Treatise on the Differential Calculus' (in the third volume of the quarto edition), in the Appendix to the Cambridge translation of Lacroix, or in the article on 'Probability' in the 'Encyclopædia Metropolitana.' Its principal use is in the solution of equations of differences, and in the deduction of theorems connected with that subject.

GE'NESIS, THE BOOK OF, is the first of the five books of Moses, and derives its name from the principal event recorded in it, namely, the creation of the world and the human race, which in the Septuagint Greek translation is expressed by the word *Genesis* (Γένεσις), "creation," or "production." In the original Hebrew it is named, according to the usual custom, from the first word in the book, *Bereshith* (בְּרֵאשִׁית), "In the beginning." It is also the first book of the Pentateuch, so called from the Greek πεντε, 'five,' and τευχος, and 'implement' or 'volume;' that is, the five-fold volume, which comprises the five books of Moses,—Genesis, Exodus, Leviticus, Numbers, and Deuteronomy,—and which down to the present time form one continuous rolled volume in the Hebrew manuscripts.

It has been thought by many critics that the book of Genesis was not written by Moses. There are some passages in it which evidently could not have been the composition of Moses, since they refer to events which happened after his death. See c. xiii. 18, c. xxiii. 2, and c. xiv. 14, where Hebron and Dan are mentioned, which, we learn from other parts of the Bible, had different names in the time of Moses. See also Gen. xxxvi. 31, where an allusion is made to the kings of Israel, and a list is given (31—43) of the princes of Edom, which is the same as the list given in Chronicles i., c. i. 43—54. But these and similar passages might easily have been inserted in later times. Dr. Graves, in his 'Lectures on the Pentateuch,' and Faber, in his 'Horæ Mosaicæ,' show that there is no other period in the history of the Jews to which its composition can be so well referred. The preface to the first volume of the last edition of Rosenmüller's 'Scholia in Vetus Testament,' contains a fair view of the controversy, in which he gives many reasons for relinquishing the opinion he formerly held, that the book of Genesis was not written by Moses.

Supposing Moses to have been the author, it becomes an interesting question to ascertain in what manner Moses was enabled to give a faithful history of events which happened so many centuries before his own age. The book must have been composed in one of three ways: 1st, by immediate revelation of every circumstance from God; 2nd, by a collection of ancient traditions; or 3rd, from former documents. The first supposition is generally abandoned in the present day by all theologians, with the exception of those who believe in the verbal inspiration of the Scriptures. The second, which is a common opinion amongst theologians in this country, would not injure the credibility of the book: since Lamech, the father of Noah, was contemporary with Adam; Shem, the son of Noah, lived in the time of Abraham; his son Isaac was contemporary with Joseph; and some of the contemporaries of Joseph might have known Moses; so that few persons were required for the transmission of the traditions. The third opinion is the one generally received by the German theologians of the present day: that they were few, is most probable, but the existence of written documents anterior to the time of Moses is unquestionable. In Genesis xxvii. the blessing of Isaac on his sons, and in xlix. the dying address of Jacob, are both apparently given verbatim. This opinion is strengthened by the fact that, in other books of the Pentateuch, reference is made to pre-existing sources. In Numbers xxi. 14, there is an avowed quotation, "It is said in the book of the wars of the Lord," &c.; and in xxiii. and xxiv. are given the hymns or parables of Balaam in his own words. This does not detract from, but rather adds to, the belief that the books were the inspired compositions of Moses; for though he may have used such pre-existing documents, and though his knowledge of many of the events might have been derived from contemporaries,—as, for instance, the Egyptian relation of the history of Joseph,—inspiration was not less necessary to enable him to distinguish the true from the false, and, while it was not needed in the case of the outward facts of Joseph's life and adventures, without it he could not have developed the scope of the mystery of Providence in those events as affecting the whole remaining history of the Hebrew nation. For a further investigation of this point, see Turner's 'Companion to the Book of Genesis,' New York, 1841. As to the attempts to prove a multiplicity of authorities from the designation of the Deity by different names,—as Elohim, God; Jehovah, Lord; and Jehovah-Elohim, Lord-God,—Hengstenberg, in his 'Authentie des Pentateuches,' has proved that the variation is always adapted to the sense of the passage in which the writer has used it, and never arbitrarily or uncertainly. Ranke ('Untersuchungen über der Pentateuch,' 1840), Dreschler ('Die Einheit und Aechtheit der Genesis,' 1838), and Mr. Turner, have taken the same view, and their works contain disquisitions on these various significations, by which they endeavour successfully to establish grounds of their hypothesis.

Objections have likewise been urged against the account of the Creation in the book of Genesis, as not agreeing with the facts of geology and natural history. These have been met by Dr. Pye Smith ('Geology and Scripture'), Dr. Redford ('Holy Scripture Verified'), Hugh Miller ('Footprints of the Creator'), and others, to whose works we refer the reader.

The chronology of the book of Genesis has occasioned great difficulty. This arises from the difference of the Hebrew text from the Septuagint. According to the Hebrew text, the Deluge happened A.M. 1656; according to the Septuagint, A.M. 2262; the former giving B.C. 4004, and the latter B.C. 5411, as the epoch of the Creation. Dr. Hales, with many other critics, considers the dates of the Septuagint to be more in accordance with profane history and with the various events related in the first chapters of Genesis. Our limits prevent us from giving an account of the controversy; we can only refer to the arguments in Dr. Hales' 'Analysis of Chronology,' vol. i. 273–303, and Clinton's 'Fasti Hellenici,' vol. i. pp. 283–301, the latter of whom defends the chronology of the Hebrew text, and observes, with much justice, that there does not appear any sufficient reason for inducing the Jews to change the numbers, while the translators of the Septuagint were naturally anxious to make the epoch of the Creation more conformable with the high pretensions of the Egyptians and Chaldæans. From the Deluge to the common date of the birth of Abraham, the Hebrew text gives 292 years, the Septuagint 1072. This date is given on the authority of Gen. xi. 26: "And Zerah lived 70 years, and begat Abram, Nahor, and Haran." But there is sufficient reason for believing that Abraham was not born till 60 years afterwards, and that his name is only placed first on the catalogue on account of his celebrity, not because he was the first-born. Adding 60 years to the former numbers, we obtain the birth of Abraham according to the Hebrew text, A.M. 2008, or B.C. 1996; according to the Septuagint, as corrected by Dr. Hales and Mr. Clinton, A.M. 3258, or B.C. 2153. Having obtained the birth of Abraham, there is no great difficulty in ascertaining the dates of the principal events that follow. The following table is abridged from Clinton's 'Fasti Hellenici;' the dates are reckoned from the birth of Abraham:—

Birth of Abraham in 130th year of Zerah. Gen. xi. 32, xii. 3–5, compared with Acts vii. 4.

10. Birth of Sarah, ten years younger than Abraham. Gen. xvii. 17.
75. The call of Abraham. Gen. xii. 1–4.
86. Birth of Ishmael. Gen. xvi. 16.
100. Birth of Isaac. Gen. xvii. 17.
137. Death of Sarah, at the age of 127. Gen. xxiii. 1, 2.
140. Marriage of Isaac, at the age of 40. Gen. xxv. 20.
160. Birth of Esau and Jacob. Gen. xxv. 26.
175. Death of Abraham. Gen. xxv. 7, 8.
237. Jacob goes to Haran at the age of 77.
257. Jacob returns to Canaan. Gen. xxxi. 41.
268. Joseph, at the age of 17, sold into Egypt. Gen. xxxvii. 2.
280. Death of Isaac, at the age of 180. Gen. xxxv. 28.
281. Joseph, at the age of 30, governor of Egypt. Gen. xli. 46.
290. Jacob, at the age of 130, goes into Egypt. Gen. xlvii. 9.
307. Death of Jacob, at the age of 147. Gen. xlvii. 28.
360. Death of Joseph, at the age of 110. Gen. l. 26.

The following passages are supposed by most Christian divines to be prophecies relating to Christ:—iii. 15; xii. 3; xviii. 18; xxii. 18; xxvi. 4; xxviii. 14; xlix. 10.

(Eichhorn's *Einleitung in's Alte Testament*; Augusti's *Grundriss einer historisch-kritischen Einleitung in's Alte Testament*; Faber's *Horæ Mosaicæ*; Graves *On the Pentateuch*; Rosenmüller's *Scholia*; Holden's *Dissertation on the Fall of Man*; Horne's *Introduction to the Scriptures*; Von Bohlen, *Die Genesis übersucht, mit Aumerkkungen*, 1835; Tush, *Kommentar über die Genesis*, 1838.)

GENEVA; GIN; HOLLANDS. There is a confusion in the popular meaning of the names of these three kinds of distilled liquor. Geneva is frequently confounded with gin. It is, however, a fermented liquor, which bears the same relation to gin as wine does to any distilled spirit. It is procured by the fermentation of the berries of the *Juniperus communis*. These berries consist of a peculiar saccharine principle (which exists to the amount of about 33 per cent. along with acetate of lime), and a volatile oil, which is contained in peculiar cells lying close to the seeds; as the oil assumes a resinous state in old berries, these cells may be easily seen in such specimens. The green one-year-old berries contain much more volatile oil, and are to be preferred to the ripe berries. The oil rarely exceeds one per cent. From the quantity of sugar which they contain the berries can easily be caused to ferment and yield a spirit, or vinegar may be made from them. Geneva is a very powerfully stimulating liquor, containing a large proportion of alcohol. The volatile oil having a special action on the kidneys renders it the most proper cordial in cases of dropsy from debility, or even connected with diseased heart, when the system requires support. The usual acceptation of geneva as a beverage is incorrect; nothing deserving of the name is sold in the spirit-shops of this country.

There appears to be no real difference between the so-called *Geneva* and *Hollands*; indeed these two names, as well as *Hollands Gin*, are now only different designations for the same liquid; but originally, as just observed, Geneva (not named from the Swiss city, but from the French name, *genièvre*, of the juniper), was a different liquid. Hollands, or Hollands geneva, or Hollands gin, is a kind of corn-spirit, which was originally wholly imported from Holland. The best kinds now made are those of Schiedam, Rotterdam, and Weesoppe, by various distillers, each of whom has his own peculiar process. Strasburg turpentine, fennel seeds, oil of fennel, and hops are used, as well as juniper, as flavouring ingredients; but it is supposed that the superiority of Hollands geneva over English gin depends rather on some peculiar mode of manufacture than on the ingredients employed, and on the fact that it becomes *aged*, or *mellowed*, or *creamed*, by remaining some time in bond before use. Some of the English rectifiers endeavour to produce a spirit exactly like Hollands; but a difference can always be detected by good judges. Pure Hollands have less acidity than any other spirit in common use. Concerning the more familiar liquid, *gin*, this name was an abbreviation of *Geneva*, and was adopted when English rectifiers began to make a liquid that might share the favour with which Hollands geneva was regarded. English gin, in the present day, consists of plain corn spirit, flavoured with oil of turpentine, and with a small quantity of other substances. Juniper may possibly be an essential element in Hollands geneva, but it is not in English gin. Each rectifier has a recipe of his own, which he does not divulge; and hence the difference in flavour between Booths', Hodges', Smith's, Nicholson's, Bristol, Plymouth, and other kinds of gin. Of all these it can scarcely be said that one is better than another, only that they differ, as one kind of London porter differs from another. Different kinds of gin have the plain-gin flavour, the Hollands flavour, the whiskey flavour, the smokey flavour, &c.; some are intended to present the qualities of fulness or richness, others piquancy or biting, &c.; and all these differences depend on the vegetable substances distilled with or added to the crude spirit—such as sugar, juniper, bitter almonds, turpentine, creosote, lemon, cardamoms, carraways, cassia, garlic, Canada balsam, Strasburg turpentine, horse-radish, grains of paradise, cayenne pepper, and various other berries, seeds, fruits, herbs, &c. Sometimes such chemical agents as sulphate of zinc, caustic potash, and sulphuric acid, are added; but this is usually for some fraudulent purpose. It is believed that London gin, *as retailed*, is more frequently adulterated than any other; because there is a taste in the metropolis for *sweetened* gin; and the addition of sugar masks the taste of some strong substance which has been added to facilitate a large dilution with water.

The processes of manufacturing these various kinds of spirit are described under DISTILLERY.

The importation of geneva, so called in the official returns, has varied in the last fifteen years from 130,000 to 430,000 gallons per annum; but there are other kinds, called "other foreign and colonial spirits," distinct from geneva, rum, and brandy, of which quantities have been imported varying from 30,000 to 1,100,000 gallons annually, and which are probably varieties of corn-spirit. This last-named entry has rapidly increased within the last few years. The computed real value of the geneva and corn-spirit imported in 1858 was about 130,000*l.* The British spirit charged with home duty, most of which is either gin or whiskey, has varied from 20,000,000 to 26,000,000 gallons yearly in the last few years. The difference between gin and whiskey, chemically and commercially, is noticed under DISTILLERY.

GENII, called in the East *Ginn* or *Djinn*, are supposed to be a race of beings created from fire, capable of assuming any form and becoming invisible at pleasure. All Moslems are obliged to believe in their existence, since they are said in the Koran (c. vi.) to be created by God. It is imagined that they inhabited this world many ages before man was created, and were governed by forty successive monarchs of the name of Solomon, the last of whom was called Gân Ebn Gân, and that from him they derived their name. It is also said that they frequently rebelled against God, who at length deprived them of their possessions and gave them to man. We learn from the Koran (c. 72) that many of these wicked spirits were converted by hearing Mohammed reading a portion of it, and that those who continue unbelievers (called, in c. 27, *Ifrit*) will be condemned to the fires of hell. They are believed to take great interest in human affairs, and to be the authors of much happiness and misery to mankind. (An interesting account of the superstitions of the modern Arabs respecting Genii is given in Lane's 'Modern Egyptians.') The belief in such an intermediary class of beings between divinity and humanity has been very extensive. The Greeks had their *δαίμονες*; the Romans their Genii [GENIUS]; the Chinese have their good and evil beings, and every town or province chooses one for its protector, to whom the governor prays, on his admittance to office, for support and assistance in his charge; and the Africans have their fetishes. It must be admitted, however, that none are so fanciful and poetical as the genii of the orientals.

The Roman genii are represented in works of art as winged figures; they are frequently figured contending in chariot races: in friezes in the British Museum their chariots are drawn by dogs, but they often are seen driving horses. Genii are commonly introduced by sculptors on monuments, &c.; sometimes they carry a cornucopia; at others they support the portrait of the deceased, or bear his armour, &c.

GENITIVE. [ABLATIVE CASE.]

GENIUS, in its original acceptation, denoted the tutelary god or dæmon which, according to an ancient and common superstition, was allotted to every individual at his birth, to guide and rule him during life, to preside over his fortunes and destiny, and eventually to lead him from existence; and it was supposed that the variety observable in the characters and capacities of different men was dependent upon the higher or lower nature of their attendant genii. Afterwards the word came to signify the disposition itself, without reference to its supposed cause; and lastly, in modern times it has been employed, in a restricted but peculiar sense, to designate either that high mental pre-eminence which is occasionally found in a few individuals, or, by a metonymy, the person possessed of such rare excellence.

Like every thing else that is truly beautiful and great, Genius has in it a something undefinable; and hence the variety of notions as to its origin and nature, in all of which there is and must be something deficient. Dr. Johnson's definition ('Life of Cowley,') is this: "The true genius is a mind of large general powers accidentally determined in some particular direction." Generally it is understood to be the perfection of human intelligence. And as this consists in the highest possible activity of the mental energies, genius is essentially creative, and all its productions are indelibly stamped with the impress of originality and grandeur. It is at once a law and a model to itself; it produces what has never before been accomplished, and which all, in all ages, are constrained to admire. It receives therefore its impulse from enthusiasm, for nothing great can be accomplished without that enthusiasm which is enkindled by some dominant idea, to which all else is made subordinate and postponed; and its chief faculties are the reason and the imagination, which alone are inventive and productive.

But according as one or other of these faculties predominates, genius becomes either scientific, artistic, or poetic. In the first case it seizes at once those hidden affinities which otherwise do not reveal themselves, except to the most patient and rigorous application; and as it were intuitively recognising in phenomena the unalterable and eternal, it produces truth. In the two latter, seeking to exhibit its own ideal in due and appropriate forms, it realises the infinite under finite types, and so creates the beautiful.

But even the most eminent genius must duly form and develope itself by a careful contemplation of the beautiful and true which the great geniuses of past time may have created and discovered. It is by looking exclusively to this circumstance, that those who deny any original inequality among men have been led to maintain that what is called genius is simply a result of education and culture; while on the other hand an equally partial consideration of those extraordinary powers which have occasionally been exhibited in totally uneducated minds, and under the most unfavourable circumstances, has deceived the zealous partisans of original genius.

In active life the grand and ambitious designs of successful statesmen and conquerors are often ascribed to genius, but they belong more properly to the energy of the will than to that of the intellect, to force of character rather than to power of mind.

The phrase "universal genius," in order to be legitimate, requires to be limited in one or other of its terms. When applied to a Fontenelle we must restrict the signification of genius to the power and capacities of the human mind in general; and it is only by confining the term universal to all the subordinate branches either of art or science, that it is even allowable to ascribe it to the genius of a Shakspere, a Michel Angelo, or a Leibnitz.

Genius and fancy are often confounded: the latter is undeniably a pre-eminent capacity, but it exerts itself rather to imitate than to invent, and is devoid of all enthusiasm.

GENOUILLÈRE. This is the term applied in fortification to that portion of the interior slope of the parapet, which is below the sill of the embrasure and in front of and covering the gun-carriage.

GENTIA'NA LU'TEA, a perennial plant, common in the mountainous and sub-alpine districts of Switzerland, Germany, &c. Though the whole plant is bitter, yet as this property is most concentrated in the root, that part only is officinal. The root should be taken up in autumn, and is best when the plant is only one year old. It is generally cylindrical, often an inch thick at the summit, but below rather branched, of a dark or brown colour externally; internally fleshy and yellow. In commerce it is met with in pieces, cut longitudinally, from six inches to a foot in length. A transverse section displays three distinct circles. The greater portion is procured from Germany; the specimens from Switzerland are generally thicker and darker coloured.

When fresh it has some smell, which is almost entirely lost by drying. The taste is at first somewhat sweet, then purely and strongly bitter. According to the analysis of Henry and Caventou, it contains a principle termed Gentianin, which is crystallisable; a volatile odorous principle, a greenish fixed oil, a free organic acid, uncrystallisable sugar, gum, colouring matter, &c. The oil is in very minute proportion; three *cwts.* yield only half a drachm of oil. The so-called gentianin consists of two distinct principles: one tasteless and crystalline, *gentisin* or *gentisic acid*, the other bitter *gentianite*.

Owing to its saccharine matter it soon moulds in a damp place, and should therefore be kept in a dry airy situation. From the abundance of the sugar, it is easily susceptible of fermentation, and from it is distilled a spirit, called Enziangeist, or "bitter snaps," much employed by the peasants on the Swiss Alps to fortify the system against the fogs and damps of these lofty regions. Strangers should be sparing in the use of this, as it contains a narcotic principle in addition to the spirit.

Yellow gentian-root is often confounded with the roots of other species of this genus, a circumstance attended with no bad consequences, but unfortunately roots of very poisonous plants, growing in the same locality, are often taken up instead of the proper one; these are, the Veratrum album (white hellebore), the leaves of which resemble those of gentian in their peculiar venation, but are alternate, while those of gentian are opposite—the root is very different, and besides this, it contains Veretria; and the Atropa Belladonna (deadly nightshade), which, besides differences in the physical characters, is devoid of the peculiar bitter of gentian, and acquires a bluish-black colour from tincture of iodine. The roots of Aconitum Lycoctonum and Ranunculus Thora are occasionally confounded with gentian-root.

Gentian-root is a pure and excellent bitter tonic, useful in all cases of debility, whether of the stomach only, or of the system generally. It possesses facilities, from not being decomposed, of being administered along with many metallic salts. It yields its properties to water, particularly when warm, to alcohol, and to wine. The simple infusion, and not the compound, of the 'London Pharmacopœia' should be employed, when any salts of iron are prescribed in the same formula. The extract is an eligible means of giving bulk, when several antispasmodic remedies, of which the dose is minute, are to be made into pills, such as oxide of zinc, protosulphate of iron, or extract of aconite. In the West Indies a preparation of gentian is used daily before meals, to give tone to the languid stomach. Stoughton's elixir, which is what is commonly used for this purpose, is only a quackish imitation of the compound tincture of gentian of the Pharmacopœia.

In the East Indies several species are used as bitter tonics. The Chirayita, or Chiretta, in the form of a cold infusion, is much prized for its tonic and febrifugal virtues. Guibourt contends that this plant is the Calamus aromaticus of the ancients, an opinion from which Dr. Royle dissents. ('Flora of the Himalaya,' p. 277.)

GENTIANIC ACID ($C_{22}H_{10}O_{10}$?); *Gentianin*; a crystalline acid extracted from the root of the *Gentiana lutea*. It is very slightly soluble in water, little more so in ether, but readily soluble in boiling alcohol. It does not redden litmus. Acted upon by nitric acid, it gives nitro-gentianic acid ($C_{22}H_8(NO_4)_2O_{10} + 2Aq.$).

GENTIANIN. [GENTIANIC ACID.]

GENTLEMAN, a corruption of *gentilhomme*, our Saxon ancestors having very early substituted "mon," or "man," for the corresponding term of the Norman-French, from which they originally received the term. Some form of this word (a compound of *gentilis* and *homo*) is found in all the Romance languages (*entil-homme* in French, *gentiluomo* in Italian, and *gentil-hombre* in Spanish), and it is undoubtedly one of the many traces of the great influence which the laws and polity of Rome exercised upon modern society and civilisation.

In the earliest form of the Roman constitution the populus, or ruling portion of the community, was divided into gentes, who were united by a common name, and the performance of certain sacred rights. Each gens was again subdivided into several familiæ, distinguished by a surname in addition to the common gentile appellation. Thus, the gens Cornelia comprised the families of the Scipiones, the Lentuli, the Syllæ, &c. Now, in default of the Agnati, or of heirs in the male line, the property of the family reverted, not to the whole populus, in whom, of strict right, the sovereignty lay, but to the gens to whom it had transferred its rights.

This right of reversionary succession, especially in the case of usufructuary possessions of the public lands, being the most valuable and important privilege of the patricians, was brought prominently forward in the quarrels between the nobles and the plebeians, and the phrase *gentem habere* (Livy, x. 8) is often employed as distinctive of the former. Afterwards, when the members of the plebs obtained the right of intermarriage with the patrician families, and an access to the honours of the state, which conferred the *jus imaginum*, or nobility, they also received the rights and privilege of *gentes*. To be admitted into a *gens*, became henceforward equivalent to a patent of nobility in modern times, and *gentilis* is accordingly widely defined by Cicero ('Top.' 6) as denoting those who were of the same name and stock, free-born, in the full enjoyment of all the rights of citizenship, and whose ancestors were always free. Hence, also, in an opposite sense, "*sine gente*" is employed by Horace ('Sat.' ii., v. 15) and Suetonius ('Tib.' 1) for ignobly born and of servile parentage.

This privilege of succession, which was called *jus gentilitatis*, or simply *gentilitas* (Cic., 'De Oratore,' i. 38), and formed one of the enactments of the Twelve Tables, was gradually undermined by the encroachments of the prætors on the civil law, and finally disappeared (Gaius, iii. 25); but the name has survived in all the languages of Western Europe.

According to Selden ('Titles of Honour,' p. 852), "a gentleman is one that either, from the blood of his ancestors, or the favour of his soveraigne, or of those that have the vertue of soveraigntie in them, or from his own vertue, employment, or otherwise, according to the customes of honour in his countrie, is ennobled, made gentile, or so raised to an eminencie above the multitude, that by those lawes and customes he be truly nobilis, or noble, whether he have any title, or not, fixed besides on him." That the word was formerly employed in this extensive signification is clear from a patent of Richard II., by which one John de Kingston is received into the estate of a gentleman and created an esquire ("Nous lui avons resceivez en l'estate de gentilhome et lui fait esquier"); and from another of Henry VI., who there, by the term "nobilitamus," creates one Bernard Angevin, a Bourdelois, a gentleman. And, according to Smith ('De Rep. Ang.,' lib. i., c. 20, 21), under the denomination of gentleman are comprised all above yeomen, whereby noblemen are truly called gentlemen.

In a narrower sense, a gentleman is generally defined to be "one who, without any title, bears a coat of arms, or whose ancestors have been freemen; and by the coat that a gentleman giveth, he is known to be, or not, descended from those of his name that lived many hundred years since." (Jacobs' 'Law Dictionary.') There is also said to be a gentleman by office and in reputation, as well as those that are born such (2 'Inst.' 668); and, according to Blackstone, quoting Sir Thomas Smith (1 'Comm.,' p. 406), "Whosoever studieth the laws of the realm, who studieth in the universities, who professeth the liberal sciences, and (to be short) who can live idly and without manual labour, and well bear the port, charge, and countenance of a gentleman, he shall be called master, and taken for a gentleman."

The learned author must have been somewhat puzzled with his definition of a gentleman, as understood in his time. Having defined a gentleman to be one who studieth the laws, &c., he adds (to be short) that he who can live idly and bear the port, &c., of a gentleman, is a gentleman; that is, if he can live idly, and if he can also do as a gentleman does (it not being said what this is), he is a gentleman. Perhaps a definition of the term, as now used, would not be easily made; it being extended by the courtesy of modern manners to many who do not come within the ancient acceptation of the term, and denied by public opinion to many whose rank and wealth do not make up for the want of other qualifications.

GENUS, in Physics, signifies a multitude or class of objects possessing some common quality or qualities. In logic it denotes the material part of the definition.

When we direct our attention to a particular object, we discover under its apparent unity a great variety of characters and qualities; and, upon an examination of several objects, we observe many points of agreement and difference between them. By the power which we possess of concentrating our faculties, we are enabled to consider these mutual relations and resemblances without any regard to their differences: we, as it were, draw the one away from the other; in short, we abstract them.

Now, by abstraction, we may either confine our view to a quality inherent in some object independently of that object; or else, neglecting the many points of disagreement which exist between a number of objects, we may seize upon the qualities that belong to all in common, in order to combine them into a single idea. In the former case the notion is simply abstract; in the latter it is abstract and general; and the multitude of objects to which we apply the general notion or common term constitutes a *genus*.

In this operation we may proceed continually by neglecting in succession a greater number of differences, and comprising under the common denomination fewer points of agreement and resemblance. In this manner we form a series of notions or genera of higher and lower order, until we ultimately arrive at the highest possible—that of *being*. In this co-ordination of genera, every intermediate genus is called a subaltern genus or species, being such in respect of different other terms; for that of which a higher genus is predicated is called a species, while relatively to all lower species it is itself a genus. Lastly, that which is not contained under any higher, is called the *summum genus*, and that under which individuals only are comprised is usually called the *infima species*.

These general notions and genera are the principles of classification and arrangement, and without them the knowledge of facts and nature itself would be, if not absolutely impossible, at best a confused mass of conceptions and objects without beauty, order, or coherence. But at the same time that we thus admit the utility of such general notions, we must remember that they are purely relative to human science and its objects; that even as such they are imperfect, and very far from conveying an adequate expression of the truth of nature, wherein there is nothing really corresponding to them, but only a something in the individual objects from which we derive them, which not only is the cause and the occasion of our forming them, but also transferring to them, as it were, a part of its own verity and existence, justifies us in according to them our confidence in science and action.

GEOCENTRIC (having the earth as centre), a term applied to the place of a planet, as seen from the centre of the earth, in opposition to its *heliocentric* place, as seen from the centre of the sun. [PARALLAX.]

GEO'DESY is that branch of applied mathematics which determines the figures and areas of large portions of the earth's surface, the general figure of the earth, and the variations of the intensity of gravity in different regions, by means of direct observation and measurement.

Some of the ancient philosophers, who lived several centuries before the Christian era, were acquainted with the nearly spherical form of the globe, and even devised methods for measuring approximately a meridional circumference. [ERATOSTHENES, in BIOG. DIV.] The Arabs long afterwards pursued the same object, and the Caliph Almamoun, in A.D. 814, ordered the measurement of a degree in the plains of Mesopotamia, an example which, after another long interval, was imitated by Snellius in Holland, Norwood in England, and by several French and Spanish mathematicians. Richer observed a variation in the length of the seconds' pendulum when sent to Cayenne by the French Academy of Sciences, the true cause of which phenomenon was explained by Newton; for the centrifugal force arising from the earth's rotation round its axis in twenty-four hours is directly opposed to the force of gravity at the equator, and in other latitudes the part of this force which acts in the direction of the plumb-line is nearly proportional to the square of the cosine of the latitude. He has also proved in his 'Principia' that a uniform fluid spheroid, in which the ratio of the centrifugal force to the attraction at the surface was the same as in the earth, would be in equilibrium when the axis of revolution was less than the equatorial diameter by 1-230th of the latter. From that time measurements have been undertaken under the directions of the various governments of Europe, to determine if the globe were really flattened at the poles, and also for the purpose of forming exact maps with respect to the latitude, longitude, and altitude, above the level of the sea, of places in their respective dominions; and lastly, the French have deduced their legal metre of length from the measurement of a particular meridian arc. Jacobi has lately shown that a revolving fluid ellipsoid, having three unequal axes, may also present a surface of equilibrium.

The result of so many geodetic enterprises has not been as successful as could be wished. Some of the earliest attempts by the French were faulty in computation, and gave results directly contrary to Newton's theory, and some able mathematicians of that day appear to have been misled by a feeling akin to envy, to the extent of supporting these false conclusions by plausible reasonings. The error of that survey has been since discovered, and all the methods which have been employed in the numerous trials undertaken in this and the last century agree in proving that the polar axis of the earth is shorter than the equatorial by about 1-300th; but they have served at the same time to demonstrate that the earth is not a spheroid, that it is not a solid of revolution, and that the figures of the northern and southern hemispheres are dissimilar. Hence if we suppose a solid of revolution having its axis in the same direction as that of the earth, and osculating the surface of the latter, the excentricity of this spheroid varies both with the latitude and the longitude of the place.

If the materials which compose the solid mass of the earth had equal capacities for heat and became liquid at equal temperatures, the spheroid of revolution would most probably be the figure assumed at the epoch when the cooling of the whole had rendered it solid. Such however is not the case; a great portion of the surface of the globe is yet liquid, and of the solid parts some must have assumed that state prior to others. It is also possible that the temperature of space is variable within the extent of the solar system, and therefore the conditions for the cooling of the northern and southern hemispheres may be different, and a very small difference would suffice to produce, in a long series of ages, a marked difference between the temperatures of the two hemispheres, and therefore a corresponding difference would arise relative to their forms. The general sphericity of the earth cannot be otherwise conceived than by its primitive fluidity, and the irregular cooling of its parts accounts sufficiently for the observed departures from the spheroidical shape, which would have been otherwise produced by the attraction of its parts and the centrifugal force of rotation. The other bodies of the solar system which have short periods of rotation present the analogous appearance of unequal axes, the equatorial axis being always the longer.

In the trigonometrical survey of portions of the earth's surface, the extent or area may be computed more and more approximately by the suppositions of such portions being plane, spherical, spheroidical, and lastly of being coincident with the osculating spheroid.

As the method of conducting ordinary surveys for topographical purposes will be explained under another head [SURVEYING], we shall here treat of geodetical measurements in reference only to general geography and the figure of the earth. We propose therefore to give a short historical notice of the principal trigonometrical surveys which have been undertaken in different parts of the world for measuring terrestrial degrees, or accurately delineating considerable portions of the earth's surface; to describe the general nature and objects of the operations to be performed in carrying on such surveys, and the principles upon which the computations are made; and to state the dimensions of the earth, considered as the spheroid of revolution, which have been deduced from the comparison of those measures of meridional arcs which appear to have been executed with the greatest precision.

The merit of first applying trigonometry to geodetic operations belongs to Willebrord Snell [SNELL, in BIOG. DIV.], who in 1617 undertook a survey of Holland, for the double purpose of establishing the geographical positions of the principal cities in that country, and measuring a degree of the terrestrial meridian. The method which he followed was the same in principle as that which would be adopted at the present time. Having formed a series of triangles extending over the country, he observed their angles with a quadrant, and computed their sides from a base which was carefully measured with wooden perches on the ground. He also determined the direction of the meridian at Leyden, and observed its inclination to a side of one of his triangles, and thereby obtained the bearings of the different angular points. Lastly, by observing the altitude of the pole-star with a five-feet quadrant at Alkmaar, Leyden, and Bergen-op-zoom, he determined the amplitudes of two celestial arcs; and on comparing the amplitudes with the terrestrial distances computed from the triangles, and reduced to the direction of the meridian, he concluded the length of a degree to be 28,500 Rheinland perches, or 55,100 French toises, equivalent to about 66¾ English miles. The result is about three miles too small. In 1621 Snell measured a new base, and was preparing to correct some errors which he had detected in the calculations, when his labours were cut short by his early death. Musschenbroek, a century afterwards, re-observed the latitudes, and revised the calculations, and found 1° = 57,003 toises, or 69 miles. (Snellius, 'Eratosthenes Batavus de Terræ ambitus vera quantitate,' &c., Lugduni Bat., 1617; Musschenbroek, 'Dissertationes Physicæ,' &c., Ib., 1729.)

About the middle of the same century Riccioli and Grimaldi undertook to measure an arc of a great circle of the earth in Lombardy. They formed a chain of triangles between Bologna and Modena, observed their angles with a quadrant, and computed their sides from a base measured on the road leading out of Bologna. The distance between the two cities was found to be 20,439 paces. Instead of reducing this distance to the meridian, according to the method of Snell, Riccioli sought to determine the arc of the vertical circle in the heavens intercepted between the zeniths of the two stations. This determination, which presumes an accurate knowledge of the latitudes and the declinations of the stars, could not, in the state of astronomy at that time, be made with sufficient precision, and accordingly the result was still more erroneous than that of Snell. He found the amplitude of the celestial arc to be 19′ 25″, whence 1° = 63,159 paces of Bologna, or nearly 74½ English miles. (Riccioli, 'Geographiæ et Hydrographiæ Reformatæ Libri XII.,' &c., Bononiæ, 1661.)

Picard, in 1669, undertook to measure the meridional arc between Paris and Amiens. This operation was conducted with far greater precision than any previous one of the same kind, and the result had a memorable application, as it furnished Newton with a sufficiently accurate knowledge of the earth's diameter, and consequently of the dimensions of the lunar orbit, to enable him to compute the force of terrestrial attraction at the distance of the moon, and thereby establish the law of gravitation. The angles were measured with a quadrant, furnished with telescopes having cross-wires in their foci (an improvement in the art of observing then newly introduced), and the sides computed from a base of 5663 toises. The latitudes were observed with a zenith sector at Malvoisine (near Paris), at Amiens, and at an intermediate point, so that two comparisons of celestial and terrestrial arcs were obtained, the mean of which gave 1° = 57,060 toises, equivalent to 364,876 English feet, or about 69·1 miles. This is a very near approximation to the true length of the degree at the same place, as it is given by recent and more exact determinations, but it proceeded, in part, from an accidental compensation of errors. (Picard, 'Mesure de la Terre,' folio, 1671; 'Dégré du Méridien entre Paris et Amiens, par M. Picard, avec les Observations de MM. de Maupertuis, Clairaut, Camus, Le Monnier, 8vo.' 1740.)

Picard's measurement gave rise to a more extensive operation,—the prolongation of the meridian through the whole extent of the French territory, and the construction of a geometrical map of France. The triangulation for this purpose was begun in 1683 by Dominic Cassini, but after a few angles had been measured, the work was suspended till 1700, when it was resumed, and in the following year the triangles were extended to the Pyrenees. The northern part, from Paris to Dunkirk, was completed by James Cassini, in 1718. Cassini adopted Picard's base, but two bases of verification were measured near the extremities of the arc. A very unexpected result was deduced from this operation. On comparing the celestial arc with the measured distance between the parallels of Paris and Collioure (the southern extremity), the length of the degree was found to be 57,097 toises, while the arc between Paris and Dunkirk gave 1° = 56,956 toises. From this it appeared that the degrees of the meridian become shorter as the latitude increases—a consequence directly opposed to the theory of attraction. (Cassini, 'Traité de la Grandeur et de la Figure de la Terre,' Paris, 1720; Amsterdam, 1723.)

The discussions to which this result gave rise in the Academy of Sciences were the immediate cause of the two celebrated expeditions to Peru and Lapland, which a few years later were undertaken under the auspices of the French government for the purpose of definitively settling the question of the compression of the earth. In 1735 Bouguer, La Condamine, and Godin, members of the Academy, set sail for Peru, where they were joined by two Spanish officers, Juan and Ulloa. From the unfavourable nature of the country, the defective state of their instruments, and other causes, this party encountered very great difficulties, and several years elapsed before they were enabled to complete their object. An arc was at length measured on the plain of Quito, between the parallels of 2′ 31″ N. and 3° 4′ 32″ S. lat. A primary base of 6274 toises was measured by Bouguer and Godin separately; and a base of verification at the southern extremity of 5259 toises was found to differ less than a toise from the length computed from the first base through the series of triangles. The measuring-rods were of deal, 20 feet in length, and compared daily with an iron toise, which from this application has been called the toise of Peru, and become celebrated in the history of geodesy, being in fact the standard to which all the degrees measured on the Continent have been ultimately referred, and in terms of which the greater number of them have been expressed. The angles were measured with quadrants of 2½ feet radius, and reduced to the horizon by calculation; in some instances the difference of altitude of two signals observed from the same station exceeded a mile. The latitudes at the extremities were observed simultaneously with zenith sectors. Three different results were computed. Bouguer found the length of the degree, reduced to the sea-level, to be 56,753 toises at the temperature of 13° of Réaumur's scale (61¼° Fahrenheit); Condamine found 56,749 toises, and the Spanish officers 56,768 toises. (Bouguer, 'La Figure de la Terre,' &c., 1749; Condamine, 'Mesure des Trois Premiers Dégrés de Méridien dans l'Hemisphère Australe,' 1751; Juan and Ulloa, 'Voyage Historique de l'Amérique méridionale,' 1752.)

While Bouguer and his associates were carrying on their operations in Peru, an arc of the meridian was measured near the polar circle by Maupertuis, Clairaut, Camus, Lemonnier, and Outhier. This party reached Tornea, at the extremity of the Gulf of Bothnia, in 1736, and established a chain of triangles along the line of the river stretching northward to the parallel of 66° 48′ 22″ N. lat. A base was measured on the frozen surface of the river. The latitudes were observed with a zenith sector by Graham. The amplitude was found to be 57′ 29″·6, and the terrestrial distance between the parallels 55,023 toises; whence 1° = 57,422 toises, exceeding Picard's degree by 362 toises. This result (which however is now supposed to err considerably in excess) put an end to all doubts respecting the decrease of the meridional degrees on going from the equator, and the consequent compression of the earth at the poles. (Maupertuis, 'La Figure de la Terre déterminée par les Observations au Cercle Polaire,' 1738.)

Soon after the return of Maupertuis and his party from the polar circle, an important survey was undertaken in France by Cassini de Thury and Lacaille, for the purpose of verifying the former measure of the meridian and laying the foundation of an accurate map of the kingdom. Six new bases were measured, each twice; that near Paris five times. The angles were observed with a 2-feet quadrant, and were reduced to the horizon and centre of the station. The latitudes were observed at the extremities and three intermediate stations; and the length of the degree deduced from each of the four arcs. The results are not now important, as the same arc has since been measured with still greater precision by Mechain and Delambre. In the course of the operation the length of a degree of longitude was also determined. The terrestrial arc extended across the mouth of the Rhône from Cette in Languedoc to Mont St. Victoire in Provence; and the difference of longitude was found by exploding gunpowder in the open air at an intermediate station, and noting the difference of the apparent times at which the flash was seen at both extremities. ('La Méridienne de l'Observatoire Royal de Paris Vérifiée, &c.,' 1744.)

In 1751 Boscovich and Lemaire began a survey of the Papal States, and in the course of the operation determined the meridional distance between the parallels of Rome and Rimini. The sides of the triangles were computed from a base measured on the seashore near the latter place, which consisted of two parts making an angle of 170° 52′ 15″. Another base was measured on the Via Appia, near Rome. The angles were observed with a quadrant of 3 feet, and the latitudes with a sector of 9 feet. The result gave 1° = 56,979 toises; but it has been shown to be affected with errors of considerable magnitude. (Boscovich, 'De Litteraria Expeditione per Pontificam Ditionem ad dimentiendos duos Meridiani Gradus, &c.,' Romæ, 1755; De Zach, 'Correspondance Astronomique,' vol. vi.)

Lacaille, in 1752, measured an arc of meridian at the Cape of Good Hope. The two extremities were connected by two large triangles, whose common side was deduced by means of two small triangles from a base of 6467·25 toises (7·8 miles), situated near the middle of the arc. The amplitude (1° 13′ 17″·33) was determined with a zenith sector of 6 feet, and the angles were measured with a 3-feet quadrant. The final result gave 1° = 57,037 toises, or 364,728 English feet, which is nearly equal to the degrees measured in France, 10° farther from the equator. (Lacaille, 'Mémoires de l'Acad. Royale des Sciences' for 1751; 'Fundamenta Astronomiæ,' 1759.) It will be seen that Mr. Maclear has recently succeeded in satisfactorily accounting for this apparent anomaly.

Beccaria, between 1762 and 1764, measured an arc of the meridian in Lombardy. The instruments and methods used were similar to those of Boscovich. The amplitude was 1° 7′ 47″·7, and the length of the degree found equal to 57,468 toises. This result greatly exceeds that which other measurers gave reason to expect; and the cause has been ascribed to the disturbance of the plumb-line of the sector by the attraction of the mountain masses on which the arc abutted at both extremities. (Beccaria, 'Gradus Taurinensis,' &c., 1774.) This arc was re-measured by Plana and Carlini in 1822, who found the amplitude to be 1° 7′ 31″·07, and the degree equal to 57,625 toises, a result still more at variance with other determinations.

Two surveys, executed by Liesganig in Austria and Hungary, between 1762 and 1769, have been usually cited in the history of geodetic measures, but are now known to be deserving of no credit. The Austrian operation comprehended nearly three degrees of the meridian of Vienna, from Brunn in Moravia, to Varasdin in Croatia; and since the beginning of the present century the triangles have been re-measured in the course of a general trigonometrical survey of the Austrian states. For some distance from Brunn, Liesganig's results agree with the recent ones; but in the last triangles (in consequence, it is supposed, of mistaking a signal) the errors in the length of the sides are from 1066 to 2509 toises; while that in the length of the meridional arc amounts to 4533 toises. Baron Zach, who examined the manuscripts of Liesganig, affirms that both the astronomical and geodetical observations were not only faulty and ill calculated, but designedly altered to produce a better agreement. (Liesganig, 'Dimensio graduum Meridianii Viennensis et Hungarici,' Viennæ, 1770; De Zach, 'Correspondance Astronomique,' vol. vii.)

The resolution adopted by the French Convention in 1791 to establish a decimal system of weights and measures of which the unit should be an aliquot part of the quadrant of the meridian, gave rise to a remeasurement of the meridian of Paris from Dunkirk to Barcelona. In the conduct of this survey, the most important in reference to the figure of the earth that has yet been executed, the French astronomers introduced numerous important improvements both into the theory and practice of geodesy. The northern part, from Dunkirk to Rhodez, including about two-thirds of the whole, was assigned to Delambre, and the southern, from Rhodez to Barcelona, to Mechain. Two bases were measured near the extremities; one at Melun, the other near Perpignan, by a method which will be described farther on. All the angles, geodetical and astronomical, were measured with repeating circles, and the observations were examined and compared by special commissioners, who fixed the mean values to be used, and directed the calculations. The azimuths and latitudes were determined at five stations, Dunkirk, Paris, Evaux, Carcassonne, and Montjouy, so that the whole was divided into four partial arcs, the lengths and amplitudes of which are given in the table at the end of this article. No doubt can be entertained of the excellence of the geodetical part of this celebrated operation, but the latitudes have been considered liable to some uncertainty, owing to the feeble power of the telescope and other causes depending on the nature of the instruments with which the observations were made. [REPEATING CIRCLE.] In fact, when Mechain had occasion to determine the latitude at Barcelona, which is only about a mile distant from Montjouy, he found a discordance between the results at these two places amounting to 3″, and all his efforts to reconcile or explain the inconsistency were fruitless.

From the results of this operation, compared with the degree measured in Peru, the dimensions and ellipticity of the earth were deduced, and the *mètre* determined. The earth was assumed to be a spheroid of revolution; the deduced ellipticity was 1÷334; and the *mètre*, or ten-millionth part of the quadrant of the meridian, at the temperature of freezing water, was fixed at 443,296 lines of the toise of Peru, the normal temperature of the iron toise being 13° of Réaumur, or 61° 15′ of Fahr. ('Base du Système Métrique Décimale;' 3 vols. 4to., Paris, 1805, 1807, 1810.)

The prolongation of the meridian through Spain, which formed a part of the original project, was interrupted by the death of Mechain, but was subsequently effected (1807-1809) by Biot and Arago. By means of a very large triangle, one side of which exceeded 100 miles, they connected the island of Iviza with the coast of Valentia; and another triangle carried the arc to Formentera, a small island still farther to the south. The amplitude was thus increased to upwards of 12⅓ degrees. (Biot and Arago, 'Recueil d'Observations Géodesiques,' &c., 1821.)

It is a circumstance deserving of notice, that notwithstanding the parade of a commission and the extraordinary precautions taken to ensure accuracy in the computations, a serious error was committed with respect to this arc, which was only recently detected by Puissant. It appears that, through inadvertence or the misapprehension of a formula, the distance between the parallels of Montjouy and Mola (the station on Formentera) was computed without applying the proper correction for the convergence of meridians. The distance originally given by the commissioners was 153605·77 toises; but the distance when the computation is correctly made is 153673·61 toises (Bessel, 'Astronomische Nachrichten,' No. 438), the difference being 67·84 toises. In consequence of this correction, and of the introduction of some other arcs since measured into the data for determining the figure of the earth, the length of the quadrant of the meridian expressed in terms of the legal *mètre*, according to the best determination which can at present be made of the dimensions of the earth, is 10,000,855·76 *mètres*; in other words, the legal *mètre* would require to be lengthened by about the ·00,000,856th part of itself in order to agree with the ideal *mètre*, a ten-millionth part of the quadrant of the elliptic meridian. This circumstance may serve to show the futility of any proposal to restore a lost standard from its assigned relation to the magnitude of the earth. The French *mètre* is in fact nothing more than an arbitrary part of the toise of Peru, in terms of which the bases were measured and the meridian computed.

The arc which was measured by Maupertuis and his associates in Lapland in 1736, was remeasured by Svanberg in 1801-1803, and extended in both directions so as to increase the amplitude about 40″. A new base was measured with iron bars which were compared with a standard *mètre* in Paris. The terrestrial angles, as well as the latitudes and azimuths, were measured with repeating circles, and the methods of observing and computing the results the same generally as those of Delambre. All the details of the operation appear to have been executed with great skill and ability: but by reason of the inadequateness of the instrument, the latitudes are not supposed to be very certainly determined; and there is some doubt with respect to the temperature at which the measuring-rods were compared with the standard *mètre*. The result gave 1° = 57,196 toises, which agrees much better than that of Maupertuis with other determinations. (Svanberg, 'Exposition des Opérations faites en Lapponie pour la Détermination d'un Arc du Méridien,' &c., Stockholm, 1805.)

A trigonometrical survey of Holland was executed under the direction of General Krayenhoff, from 1801 to 1809, which may be regarded as a continuation of the general survey of France. No base was measured, but the distances were computed from a side of one of Delambre's adjacent triangles. The angles were measured with repeating circles, and Delambre's methods adopted throughout. As a verification, some distances were deduced from two different series of triangles, and the greatest discordances were found to amount only to one *mètre* in 9128. ('Précis Historique des Opérations Géodésiques et Astronomiques faites en Hollande pour servir de base à la Topographie de cet état; Exécutées par le Lieutenant-Général Krayenhoff,' &c., À la Haye, 1815.)

The first geodetic survey executed in England was undertaken with the immediate object of establishing a trigonometrical connection between the observatories of Paris and Greenwich, in order to determine the difference of longitude. A memoir on the subject, drawn up by Cassini de Thury, was in 1783 presented by the French ambassador to the king, who placed funds at the disposal of the Royal Society for providing the requisite apparatus. In order to accomplish the proposed object, it was necessary to connect the observatory of Greenwich with the French arc of meridian, by carrying a series of triangles from

Greenwich to Dunkirk. This was undertaken by General Roy, who began his operations by measuring a base of 27,404 feet on Hounslow Heath in the summer of 1784. For the measurement of the angles a large and exquisitely divided theodolite, having a horizontal circle of three feet in diameter, and carrying telescopes of 36 inches focal length —an instrument far superior to any that had ever been employed in geodetical observations—was constructed by Ramsden. In the summer of 1787, the triangulation was begun by General Roy, assisted by Mr. Dalby, and before the end of the year it was carried to the eastern coast of Kent, and connected with a series of triangles on the opposite coast, which had been extended from Dunkirk to Calais and Boulogne, by Cassini, Méchain, and Legendre. Throughout the whole of this survey the practical operations were conducted with a degree of accuracy and precision, of which, till that time, there had been no example. The methods of calculations were however less excellent; the sum of the three observed angles of each triangle was made equal to 180° by an arbitrary correction, and the sides computed by plane trigonometry. By reason of the small extent of country surveyed, the neglect of the earth's curvature did not lead to any serious error, but such a method of proceeding would be inadmissible at the present day. A base of verification of 28,535 feet was measured on Romney Marsh with a steel chain, and the difference between the measured length and the length computed from the Hounslow Heath base through the series of triangles was found to be only about 28 inches. So near an agreement might afford a satisfactory proof of the general accuracy of the work, but this has since been submitted to a more decisive test. In 1821 and some of the following years, the angles were remeasured by Colonel Colby and Captain Kater, with the same excellent instrument, and the triangles calculated with reference to the sphericity of the earth. On comparing the results with those of General Roy, the greatest difference was found to be in the distance between the signals at Dover and Calais, and this amounted only to 12½ feet, the whole distance being 137,472 feet. (Roy, 'Phil. Trans.' 1790; 'Trigonometrical Survey of England and Wales,' vol. 1; Kater, 'Phil. Trans.,' 1828.)

The operations for establishing a geodetic connection between the observatories of Greenwich and Paris had the effect of suggesting the expediency of a general survey of the British isles. This great national undertaking was commenced in the year 1791. The operations were conducted by Colonel Williams, and Captain (afterwards General) Mudge, of the Royal Engineers, and Mr. Dalby, who had previously assisted General Roy. Their first step was to remeasure the base on Hounslow Heath. This was effected by means of two steel chains, each 100 feet long, which had been carefully constructed for the purpose by Ramsden. The length of the base was found to be 27404·24 feet, a result differing only 2¼ inches from that obtained by General Roy. [ROY, MAJOR-GENERAL, in BIOG. DIV.] The terrestrial angles of the survey were measured with two large theodolites by Ramsden, each 3 feet in diameter; and a smaller theodolite, by the same artist, of 18 inches diameter. In 1801, it reached Clifton in Yorkshire. The length of the arc of the meridian extending from Dunnose in the Isle of Wight to this station was determined in the following year by General Mudge. In 1806 the arc was prolonged to Burleigh Moor, about a degree to the north of Clifton. At the same time the triangulation had extended considerably over other parts of England. In the course of these operations three bases of verification were measured; one on Salisbury Plain (1794), by Lieutenant-Colonel Williams and General Mudge [MUDGE, GENERAL, in BIOG. DIV.]; one on Misterton Carr, near Clifton (1801), by General Mudge; and one on Rhuddlan Marsh, in Wales (1806), by the same officer. These various bases were measured with the same steel chains which were employed in the measurement of the base on Hounslow Heath. The astronomical latitudes of six stations on the arc of the meridian extending from Dunnose to Burleigh Moor, namely, Dunnose, Greenwich, Clifton Beacon, Arbury Hill, Delamere, and Burleigh Moor, were determined with a zenith sector of 8 feet radius, constructed by Ramsden. The operations of the survey down to 1811 are recorded in a work, the concluding volume of which was published in the year just mentioned. ('An Account of the Operations carried on for accomplishing a Trigonometrical Survey of England and Wales, &c.; by order of the Honourable Board of Ordnance,' by Captain Mudge, R.A., Mr. Dalby, and Captain Colby, R.E.; 3 vols., 1799-1811.)

The triangulation continued without interruption to be extended towards the north. In 1817, a new base of verification was measured on Belhelvie Links, near Aberdeen, by Major-General Colby, with the assistance of Mr. Gardner. The same instruments of measurement were employed on this as on previous occasions of a similar kind. In 1820, upon the death of General Mudge, General (then Captain) Colby was appointed Superintendent of the Ordnance Survey. In 1824, the operations for the survey of Ireland were commenced. A base was shortly afterwards (1827-8) measured on the shores of Lough Foyle, in the county of Londonderry. ('An Account of the Measurement of the Lough Foyle Base, in Ireland, &c.,' by Captain William Yolland, R.E., 1847.) The apparatus of measurement differed on this occasion from that employed in ascertaining the lengths of the previous bases, consisting of a combination of bars of different metals, so adjusted as, by their unequal expansion, to obviate the varying effects of temperature. A description of this apparatus, which was devised by Colby, will be given presently. The triangulation was rapidly extended over Ireland. The instruments were the same as those which had been used in the survey of England, with the addition of a 2-foot theodolite constructed by Troughton & Simms. The triangulation was connected at several points with the triangles observed in England, Wales, and Scotland. The astronomical latitudes continued to be determined with Ramsden's zenith sector until 1841, when it unfortunately was destroyed in the course of the conflagration which burned a considerable portion of the Tower of London in that year. An account of the operations with this fine instrument was published in the following year. ('Astronomical Observations with Ramsden's Zenith Sector,' 1842.) The subsequent determinations of latitude were effected with a new zenith sector, devised by Mr. Airy, the astronomer-royal, with the view of obviating certain inconveniences which attended the use of Ramsden's instrument. Three important principles of a novel character were involved in the construction of Airy's zenith sector. "The first principle was the arrangement for making successive observations in two positions of the instrument, face east and face west, at the same transit. The second was the substitution of a level, or system of levels, for the usual plumb-line. The third principle was the casting in one piece, as far as practicable, of each of the different parts of the instrument, in order to avoid the great number of screws and fastenings with which most instruments are hampered, and to secure, if possible, perfect rigidity." An account of the observations with this sector was published in 1852. ('Astronomical Observations with Airy's Zenith Sector, from 1842 to 1850,' by Captain William Yolland, R.E.)

At the stations of Balta in Shetland, Cowhythe in Aberdeenshire, and Dunnose in the Isle of Wight, the latitudes were determined first with Ramsden's and subsequently with Airy's zenith sector. A comparison of the results affords satisfactory evidence of the degree of precision attained in such observations. Thus we have—

Station.	Airy.	Ramsden.	Difference.
Dunnose . . .	50°37′6″·98	50°37′7″·09	0″·11
Balta	60 45 1 ·68	60 45 2 ·31	0 ·63
Cowhythe . .	57 41 9 ·58	57 41 9 ·74	0 ·16

In 1849 the base on Salisbury Plain was re-measured with Colby's compensation bars. The result, in combination with the Lough Foyle base, has formed the groundwork of all the subsequent computations connected with the triangulation, the other bases having been used merely for purposes of verification.

Upon the retirement of General Colby in 1847, Colonel Hall was appointed Superintendent of the Ordnance Survey. In 1858 a work was published by Colonel James, who has recently succeeded Colonel Hall as superintendent of the survey, containing a complete account of the observations and calculations relative to the triangulation of the British Isles, with an investigation of the figure, dimensions, and mean density of the earth, as deducible from the results in combination with the data of the same kind which had hitherto been established. ('Ordnance Trigonometrical Survey of Great Britain and Ireland;' 'Account of the Observations and Calculations of the Principal Triangulation, and of the Figure, Dimensions, and Mean Specific Gravity of the Earth, as derived therefrom,' drawn up by Captain Alexander Ross Clarke, R.E., &c., under the direction of Lieut.-Colonel H. James, R.E., &c., Superintendent of the Ordnance Survey, 4to, London, 1858.) The triangulation embraces an arc of the meridian extending from Dunnose in the Isle of Wight to Saxavord, the most northerly of the Shetland Isles. The former of these stations is situate in lat. 50° 37′ 3″·748; the latter in lat. 60° 49′ 41″·992. The amplitude of the arc is, consequently, 10° 12′ 38″·244.

It has been stated that the terrestrial distances were computed from the base lines measured on Salisbury Plain (1849), and on the shore of Lough Foyle, in Ireland. The difference between the measured length of each of these bases and the length computed from the other base was found to amount to 0·4178 feet, or about 5 inches. From this result a mean base has been derived by the theory of probabilities, and this mean base has been used as the immediate groundwork of all the subsequent calculations. The following table exhibits a comparison between the lengths of the bases as measured and reduced to a common standard, and their lengths as determined by the triangulation :—

Date.	Base.	Length in terms of Ordnance Standard O_1*	Length in Triangulation	Difference.
		Feet.	Feet.	Feet.
1791	Hounslow Heath .	27406·190	27406·363	+ 0·173
1794	Salisbury Plain .	36576·830	36577·656	+ 0·826
1801	Misterton Carr . .	26344·060	26343·869	— 0·191
1806	Rhuddlan Marsh .	24516·000	24517·596	+ 1·596
1817	Belhelvie . .	26517·530	26517·770	+ 0·240
1827	Lough Foyle . .	41640·887	41641·103	+ 0·216
1849	Salisbury Plain .	36577·858	36577·656	— 0·202

Many of the sides of the triangles are of great length, especially those which connect the triangulation of Ireland with the stations on the opposite coasts of England, Wales, and Scotland. The following is a statement of the sides which exceed 90 miles; the names given are those of the stations at the extremities of each side. The letters appended to each station serve to indicate whether the station is situate in England (E.), Wales (W.), Scotland (S.), Ireland (I.), or Isle of Man (I. M.):—

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* This was one of two 10 feet bars with which the compensation bars employed in the measurement of the base-lines was compared.

Side.	Length in Miles.
Slieve Donard, I.—Sca Fell, E.	111·2
Slieve Donard, I.—Snowdon, W.	108·0
Precelly, W.—Kippure, I.	107·5
Merrick, S.—Ben More, Mull, S.	107·4
Slieve Donard, I.—Criffel, S.	106·1
Jura, S.—Ben More, S. Uist, S.	106·0
South Berule, I. M.—Goat Fell, S.	104·2
Slieve Donard, I.—Goat Fell, S.	104·1
Snowdon, W.—Ingleborough, E.	102·6
Snowdon, W.—Sea Fell, E.	102·2
Culleagh, I.—Keeper, I.	101·9
Keeper, I.—Nephin, I.	98·5
Merrick, S.—Ben Lawers, S.	97·7
Precelly, W.—Mount Leinster, I.	96 9
Snowdon, W.—Ballycreen, I.	96 1
Kippure, I.—South Berule, I. M.	95·8
Kippure, I.—Guilymore, I.	95·7
Baurtregaum, I.—Knockanaffrin, I.	95·5
Knocklayd, I.—Ben Lomond, S.	95·2
Precelly, W.—Ballycreen, I.	95·1
Kippure, I.—Snowdon, W.	94·1
Culleagh, I.—Kippure, I.	93·2
Precelly, W.—High Willhays, E.	93·2
Snowdon, W.—Tara, I.	93·1
Ben Macdui, S.—Sayrs Law, S.	92·9
Ben More, S. Uist, S.—Ben Nevis, S.	92·2
South Berule, I. M.—Ingleborough, E.	92·2
Snowdon, W.—Pendlehill, E.	91·9
Ben Corr, I.—Brandon, I.	90·0

The length of the entire arc of the meridian included between Dunnose and Saxavord was found to be 3,729,334·07 feet. The distances between the parallels of Dunnose, Arbury, Clifton, Easington, and Saxavord were separately computed. The following are the results:—

	Feet.
Dunnose to Arbury	586,356·36
Arbury to Clifton	450,225·16
Clifton to Easington	404,325·22
Easington to Saxavord	2,288,427·33
	3,729,334·07

The distance between the parallels of Easington and Saxavord, which lie very nearly upon the same meridian, was computed by two different systems of triangles. The results were:—

2,288,427·29 feet, by the one system of triangles.
2,288,427·38 feet, by the other „

Mean 2,288,427·33.

By the first calculation, the distance of Saxavord from the assumed meridian at Easington was 222·56 feet; by the second calculation it was 221·94 feet. The difference of the two results amounts to only 0·62 feet.

The operations connected with the great Trigonometrical Survey of India have resulted in the measurement of an arc of the meridian which in extent is second only to the Russo-Scandinavian Arc, to be presently alluded to. This important undertaking was commenced in the year 1801, under the superintendence of Colonel Lambton. A base was measured in the neighbourhood of Madras, which served as the groundwork for the measurement of an arc of the meridian of about a degree and a half in amplitude. By a course of triangulation, Colonel Lambton subsequently advanced westward to a place called Dodagoontah, about 170 miles distant from Madras, where he measured a second base. He now directed his operations southwards, forming a chain of triangles which ultimately reached Punnæ (Lat. 8° 9′ 35″) near Cape Comorin. Bases of verification were measured both at the middle of the arc and at the southern extremity. The arc was subsequently prolonged northwards by Colonel Lambton as far as Damargida, in lat. 18° 3′ 15″. Near this station, at Beder, another base of verification was measured in the year 1815.

The amplitude of the Indian arc, extending from Punnæ to Damargida, it will be seen, now amounted to 9° 53′ 40″. With the view of prolonging it still further north, Colonel Lambton measured a base near Takal Khera, which he intended to be the limit of the next section of the arc. Upon the death of that officer in 1823, Colonel (then Captain) Everest was appointed his successor, by whom the triangulation was continued from Damargida to Kalianpur, in lat. 24° 7′ 11·8″ near which, in the plain of Seronj, another base of verification was measured.

The base lines determined by Colonel Lambton and Colonel Everest in the course of the operations to which allusion has just been made, were measured with a steel chain a hundred feet long, as in the case of the earlier measurements of a similar kind connected with the survey of the British Isles. The terrestrial angles were measured with a theodolite, 3 feet in diameter, constructed by Cary, and the latitudes were ascertained with a zenith-sector of 5 feet radius, by Ramsden. It would appear, according to the candid exposition of Colonel Everest, that the results of Colonel Lambton's operations, and of those hitherto conducted by himself, are not entitled to so high a degree of reliance as the present advanced state of geodesy demands. The azimuthal circle of the great theodolite had received an accidental blow, and although Colonel Lambton had, to a great extent, succeeded in obviating the effects of the injury, still the subsequent use of the instrument, even with the utmost precaution, could not be regarded as altogether unexceptionable. Again, it was found that previous to the measurement of the base at Takal Khera, the joints of the chain were found to be thickly covered with rust, the removal of which could scarcely have failed to affect the length of the chain. In the measurement of the base, the chain was not supported on coffers, or stretched by a constant weight. The process employed was to lay it on the ground and stretch it by means of a hand-capstan. The length of the Beder base when computed through the series of triangles from the base at Takalkhera was found to differ from its measured length by 78·72 inches. It was clear therefore that the results did not possess all the precision desirable in such important operations. Great allowance must, however, be made for the difficulties arising from the climate and other unfavourable circumstances. (Lambton, 'Asiatic Researches,' vols. viii., x., xii., xiii.; 'Phil Trans,' 1818; Everest, 'Account of the Measurement of an Arc of the Meridian between the Parallels of 18° 3′, and 24° 7′, &c.', 1830.)

Colonel Everest, who had been compelled by ill-health to proceed to England, returned to India in 1830, with the view of resuming his geodetical labours. For this purpose the East India Company had provided him with an ample supply of instruments of the very first quality. He commenced his operations with the measurement of a base at Dhera Dun, near Kaliana, in lat. 29° 30′ 48″, about 70 miles from the foot of the Himalayas. On this occasion the measurement was effected with bars provided with Colby's compensation apparatus. From Kaliana the triangulation was extended southwards until at length in 1837 it reached Kalianpur, the northern extremity of the great arc. Upon computing the length of the Seronj base, which had been measured in 1824, from the recently measured base at Dhera Dun, it was found that the measured and computed results differed to the extent of 3½ feet. In consequence of this discordance, Colonel Everest measured the Seronj base anew. This important operation was brought to a close in the early part of 1838. It appeared from the result that an error of nearly 3 feet had been committed in the measurement of 1824.

In order to remove all suspicion from the measurement of the arc included between Damargida and Kalianpur, Colonel Everest, taking advantage of an interruption of his labours, occasioned by the necessity of modifying the instruments for determining the celestial amplitudes, resolved to determine afresh the whole terrestrial distance between those two stations. The triangulation was effected by Captain Waugh and Captain Renny. In 1840 a new base was measured by Captain Waugh in the vicinity of Damargida. It was found impossible to identify the site of the old Beder base measured by Colonel Lambton in 1815. The results of the new base measurements were found to be extremely satisfactory. The length of the Dhera Dun base, when computed from the Seronj base, was 39183·273 feet. The measured length was 39183·873 feet. The difference consequently amounted to only 0·600 feet, or rather more than 7 inches, while the distance between the two bases was about 480 miles. The result of a comparison of the measured length of the Beder base and its length as computed from the Seronj base was equally satisfactory. In this case, although the distance between the two bases amounted to 426 miles, the difference between the measured and computed results was only a little more than 4 inches.

For ascertaining the amplitudes of the two sectional arcs, Kaliana-Kalianpur, and Kalianpur-Damargida, Colonel Everest employed the method founded on simultaneous observations, at the extremities of each arc, of the zenith distances of certain stars selected beforehand for the purpose. The observations were made with two vertical circles, 3 feet in diameter. The amplitude of the northern section was determined by observations of thirty-six stars, one half to the north and the other half to the south of the zeniths of both stations. The observations at Kaliana, which were made by Colonel Everest and Captain Renny, were nearly, but not quite, simultaneous with those made at Kalianpur by Captain Waugh. For the determination of the amplitude of the southern section of the arc, extending from Kalianpur to Damargida, thirty-two stars were simultaneously observed. The results gave 5° 23′ 37″·051 for the amplitude of the arc between Kaliana and Kalianpur, and 6° 3′ 55″·973 for the amplitude of the arc between Kalianpur and Damargida. The amplitude of the entire arc measured by Colonel Everest consequently amounts to 11° 27′ 33″·024. If to this we add 9° 53′ 40″, the amplitude of the arc measured by Colonel Lambton, we obtain 21° 21′ 13″·024 for the entire length of the great meridional arc of India. ('Account of the Measurement of Two Sections of the Meridional Arc of India, Bounded by the Parallels of 18° 3′ 15″; 24° 7′ 11″; and 29° 30′ 48″.' By Lieutenant-Colonel Everest. London, 1847.)

The great meridional arc of Russia originated in the operations connected with the trigonometrical survey of the Russian empire.

In 1819, M. Struve, who was then director of the observatory of Dorpat, while engaged in the survey of Livonia, suggested to the university of Dorpat the desirableness of measuring the arc of the meridian included between the island of Hogland in the Gulf of Finland, and the town of Jacobstadt in the province of Courland. The sanction of the emperor having been obtained for the project, the operations were commenced, and were finally completed in the year 1827. The terrestrial angles were measured with Reichenbach's *Universal Instrument*. The latitudes of the stations were determined by observations with a transit adjusted in the prime vertical. The arc measured 3° 35′ 5″, and passed very nearly through the meridian of the observatory at Dorpat. In the same year in which M. Struve brought to a close the operations connected with this arc, General Tenner also completed the measurement of the arc of the meridian included between Bristen in Courland, and Belin in the province of Grodno. The amplitude of this arc was found to be 4° 32′. As Belin, the northern station of this arc, was distant only 4′ 47″ from Jacobstadt, the southern station of the Livonian arc, it became desirable to connect trigonometrically the two arcs together. This was effected in 1827–8, by M. Struve and General Tenner, independently of each other, and the results upon being transmitted separately in sealed letters to Bessel, were found to exhibit a most satisfactory accordance. The amplitude of the entire arc thus measured between Hogland and Belin amounted to 8° 2′ 28″. (Struve, 'Beschriebung der Breitengrad messung in den Ostseeprovinzen Russlands,' &c. Dorpat, 1831.)

In 1845, the Russian arc was extended northwards as far as Tornea, the southern extremity of the Lapland arc. It thereby received an accession of length amounting to 5° 26′. M. Struve had for his principal coadjutor on this occasion, M. Wolstedt, who was subsequently appointed director of the Observatory of Helsingfors. While the arc was being prolonged towards the north, General Tenner was engaged in extending it southwards, until it reached the northern frontier of the province of Bessarabia. By this operation its length received a further increase of 3° 17′ 47″. The entire arc now extended from Tornea in lat. 65° 50′ 34″ to Souprounkontsi in lat. 48° 45′ 1″. It consequently possessed an amplitude of 17° 5′ 33″. In 1849 it was extended southwards through the entire province of Bessarabia to Ismail on the Danube. The amplitude of the entire arc now amounted to 20° 31′.

Under the auspices of the Swedish government the Russian arc of the meridian has been extended to the Arctic Ocean. The Norwegian portion of the arc was executed by M. Hansteen, of Christiania, and the Swedish portion by M. Selander, Director of the Observatory of Stockholm. The Swedish arc extends from Tornea in lat. 65° 51′, to Atjick in lat. 68° 54′. Its amplitude therefore amounts to 3° 3′. The Norwegian arc extends from Atjick to Fuglenaes, in lat. 70° 40′, and consequently embraces an amplitude of 1° 46′. The two arcs together measure 4° 49′.

The Russo-Scandinavian arc of the meridian now extends from Ismail on the Danube, lat. 45° 20′ 20·8″, to Fuglenaes on the Arctic Ocean, lat. 70° 40′ 11″·3. Its amplitude amounts to 25° 20′ 8″·5; and it is consequently the largest arc of the meridian which has been hitherto measured on the earth's surface. (Struve, 'Exposé historique des travaux executés jusqu'à la fin de l'année 1851, pour la mesure de l'arc du Méridien entre Fuglenaes, 70° 40′, et Ismail, 45° 20′, &c.;' St. Petersbourg, 1852.)

Two arcs of meridian have been measured in Hanover and Denmark, which, though of comparatively small extent, are very valuable by reason of the skilful manner in which the operations were conducted, and the great probable accuracy of the results. The first was obtained by connecting the two observatories of Göttingen and Altona, which are situated nearly in the same meridian, by means of a chain of triangles proceeding from a base which was measured by Gauss in 1820. From the same base another chain of triangles was carried through Denmark, by means of which the geodetical distance between the parallels of Lauenburg (in Hanover) and Lysabbel (in the island of Alsen) was computed. The celestial arc was determined by Schumacher with Bradley's zenith sector, sent from the observatory at Greenwich for the purpose. (Gauss, 'Bestimmung des Breitensunterschiedes swischen den Sternwarten von Göttingen und Altona, &c.'; Bessel, 'Astron. Nachrichten,' No. 333.)

An arc, of which the amplitude is 1° 30′ 28″, was also measured in Prussia, by Bessel, between 1831 and 1838. The immediate object of this undertaking was to connect the Russian triangulation with a chain of triangles which had been measured in the western part of Prussia, extending through Hesse, Thuringia, and Brandenburg, to Silesia, and connecting the Dutch (and thereby also the French and English) triangles with those of Bavaria and Austria. In this operation Bessel included the measure of an arc of the meridian of Königsberg. A base of 935 toises was measured with great precision. The angles were observed with a theodolite of 15 inches diameter, and the latitudes at the two extremities (Truntz and Memel) determined, as in Struve's method, with a transit-instrument adjusted in the prime vertical. The details are given by Bessel in a work which should be in the hands of every one concerned with geodetical operations of the highest order. (Bessel, 'Gradmessung in Ost-Preussen und ihre Verbindung mit Preussischen und Russischen Dreieckskotten, Berlin,' 1838.)

The anomalous nature of the result deduced by Lacaille, from his measurement of an arc of the meridian at the Cape of Good Hope, has been already alluded to. It is gratifying to learn that Mr. Maclear, by remeasuring and extending Lacaille's arc, has succeeded in completely removing the difficulty arising from this cause, and has obtained results which exhibit a most satisfactory accordance with the theory of gravitation. It is understood that the details of Mr. Maclear's labours will shortly be published. The amplitude of the arc measured by him amounts to 4° 11′ 45′ ·538. The following table exhibits a comparison between the observed latitudes at the various stations of the arc, and the corresponding latitudes calculated from Airy's elements of the earth's figure.

Station.	Observed Lat.	Cal. Lat.	Diff.
North End of arc	29°44′17″·66	29°44′17″·35	+ 0″·31
Kamies Sector Berg	30 21 29 ·10	30 21 20 ·73	+ 8 ·37
Heerenlogements Berg	31 58 9 ·11	31 58 9 ·64	— 0 ·53
Royal Observatory	33 56 3 ·20	33 56 3 ·20	. . . .
Zwart Kop	34 13 32 ·13	34 13 33 ·80	— 1 ·67
Cape Point	34 21 6 ·26	34 21 6 ·80	— 0 ·54

Mr. Maclear remarks that the disturbing effect produced by the attraction of the immense Bushman Table Land, the mean elevation of which above the level of the sea exceeds 3000 feet, is sufficient to account for the deflection observed at Kamies Berg.

We shall conclude this historical sketch of geodetical operations with a brief statement of the results deduced by Mr. Airy from the measurement of the arc of longitude comprised between the Royal Observatory, Greenwich, and Feaghmain, a station of the Ordnance Survey, situate in the island of Valentia, on the west coast of Ireland. The plan proposed by Mr. Airy, was to ascertain the difference of longitude of the two stations by the triangulations of the Ordnance Survey, assuming the elements of the earth's figure as previously determined by him, and to compare the result with the difference of longitude derived from the transportation of chronometers. The operations connected with this object were carried into effect in the year 1844. The following are the final results, the intermediate stations of Liverpool and Kingston (Dublin), through which the chronometers passed, being also included in the investigation.

	m.	s.
Geodetic arc of longitude from Greenwich to Liverpool	12	0·35
Chronometric arc	12	0·05
Chronometric arc smaller		0·30
Geodetic arc from Greenwich to Kingston	24	31·48
Chronometric arc	24	31·20
Chronometric arc smaller		0·28
Geodetic arc from Greenwich to Feaghmain	41	23·07
Chronometric arc	41	23·23
Chronometric arc larger		0·16
Geodetic arc from Liverpool to Kingston	12	31·13
Chronometric arc	12	31·15
Chronometric arc larger		0·02
Geodetic arc from Kingston to Feaghmain	16	51·59
Chronometric arc	16	52·03
Chronometric arc larger		0·44

By means of the different surveys to which we have now alluded the greater part of Europe has been covered with chains of triangles, whereby not only the geographical positions of all the principal places and remarkable objects have been determined by actual measurement, but all the measured arcs of meridian and parallel, and all the principal observatories have been trigonometrically connected with each other. The comparison of the astronomical and geodetical positions of so many connected points is, perhaps, even better calculated to lead to an accurate knowledge of the local configuration of this quarter of the globe than the measurement of isolated degrees.

We proceed now to give a general view of the methods of conducting a trigonometrical survey, and computing the results of the observations.

Measurement of the Base.—The foundation of every trigonometrical survey is the measurement of a ground-line, or base, in terms of which all the distances are to be computed. This is an operation which is attended with considerable difficulty, and requires to be executed with the most minute precision; for any error with which the result may be affected is multiplied in the sides of the triangles in the ratio of their length to the length of the base; and all other distances concluded from the survey are affected in the same proportion. An error in the base amounting only to an inch in the mile would vitiate the determination of the earth's diameter to the extent of 110 yards.

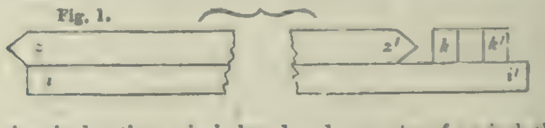
The general method of proceeding may be thus described:—A piece of ground must be selected as free from obstructions and as nearly level as possible. The terminal points must be defined by permanent marks; for example, by a fine dot, or the intersection of two straight lines, on a plate of metal, securely fixed in the ground. In order to trace the line of the base, a transit-instrument is adjusted over one of the terminal points, and directed to a flag-staff or other signal erected at the other, by which means the observer is enabled to direct an assistant to plant pickets in the ground, all ranging in the same vertical plane. The measuring apparatus may be constructed and applied in various ways, but in all cases the following conditions must be observed :—1, The successive measuring-rods (or chains) must be arranged accurately in the vertical plane passing through the terminal points of the base ; 2, the temperature of the rods must be observed at the time they are applied, and their rate of expansion determined by direct experiment, in order that the apparent lengths may be reduced to the length at a given temperature ; 3, they must be supported in such a manner as to have no tendency to flexure ; and 4, each rod, when adjusted in the line of the base, must be exactly horizontal, or its inclination exactly determined by levels, in order that the corresponding horizontal distance may be computed.

Previously to General Roy's measure of the base on Hounslow Heath the measuring apparatus used in all similar operations (with the exception of one of the bases measured by Lacaille and Cassini in France) consisted of deal rods, usually about 20 feet in length ; but deal rods, however well seasoned, are found to be considerably affected by the hygrometrical state of the air, and liable to sudden and irregular expansions and contractions, the effects of which cannot be accurately estimated, even when they are compared from time to time with a standard metallic bar. For this reason General Roy, after he had measured the base with deal rods, measured it a second time with hollow glass tubes. The tubes were 20 feet in length and about an inch in diameter, and the extremities were defined by metal buttons, ground perfectly flat, and perpendicular to the axis of the tube. At one end this apparatus was fixed to the tube ; at the other it was attached to a sort of piston, or slider, capable of being pushed up a certain way within the tube against a slender spring. A fine line marked on the slider, and another on the glass tube, were so adjusted, that when the slider was pushed up until the lines came into coincidence (which was observed through the glass), the distance between the flat ends of the metal buttons was exactly 20 feet at the temperature of 62° Fahr. In making the contacts, the flat end of one rod was pressed by a screw apparatus against the moveable end of the other, until the coincidence of the lines took place ; so that a constant pressure was applied equal to the tension of the spring. When the Ordnance survey was begun, this base was again measured with a steel chain, made by Ramsden, of 100 feet in length, and consisting of 40 links, terminated by a brass handle at each end. When in use the chain was supported on wooden coffers, raised on trestles, and stretched with a weight of fifty six pounds. The extremities were defined by marks on the brass handles ; and in order to bring the marks successively to the same point on the base-line the following contrivance was adopted : a brass scale, firmly secured to a post driven into the ground, but not connected with the chain or its supports, was placed contiguous to the preceding end, A, and adjusted by means of a screw apparatus, so that a division on the scale coincided exactly with the mark on the handle. The chain was then carried forward one length ; and when again placed on the coffers, was drawn back against the stretching-weight, until the mark on the handle at the following end, B, coincided with a division of the scale which had remained fixed in its place. In this manner the marks on A and B either occupied the same point on the line of the base, or the distance between them was known in terms of the scale. The same method was followed in measuring several other bases in England in the course of the survey, the chain being compared before and after each operation with another similar chain which was kept for this purpose. The advantage of the chain depends solely on its great length, by reason of which the number of coincidences (in making which the chief difficulty consists) is considerably reduced ; but this advantage is probably more than counterbalanced by its liability to alteration from wearing or corroding at the joints, and the insufficient security afforded that, notwithstanding the stretching, all its points are in the same straight line. The use of the chain has been confined to the English and Indian surveys, and is now abandoned in both.

The apparatus used by Delambre and Méchain in measuring the two bases in France, on which the length of the meridian depends, was constructed as follows :—The measuring rod was a thin bar of platinum, two toises in length, half an inch in breadth, and two lines in thickness. This was covered by another bar of copper, somewhat shorter, the two being firmly connected by screws at one end, but free at every other point, so that the expansions and contractions of each were not affected by the other. The relative expansions were thus indicated by the distance between the free extremities of the two bars ; for measuring which a finely divided scale was cut on a part of the platinum bar, and a vernier attached to the extremity of the copper bar. The relative expansion gave the means of computing the absolute expansion of the platinum bar at the time of the measurement. Four of these compound bars were used together ; and when all were adjusted in the line of the base, and the requisite observations made and recorded, the last was carried forward and placed first, the others being left in their places. The ends were not brought into contact ; a small interval was left between each and the next, which was measured by a slider, or small scale of platinum, attached to that end of the platinum-bar which was not covered by the copper bar. For the measure of the Hanoverian base Gauss employed three bars of hammered iron, two toises in length, and about an inch and a half in breadth and thickness, enclosed in boxes so as to leave only the ends projecting, and supported by counterpoises to prevent flexure. The ends were covered with steel plates, one flat and the other spherical ; and when the bars were placed in the line of the base, a small interval was left between the flat end of one bar and the spherical end of the preceding one, which was measured by dropping into it a thin wedge. Struve also employed iron bars in measuring the Russia base. In this case, however, the ends of the bars were brought into contact, and the contacts made on a principle similar to that which had been adopted by General Roy in using the glass rods. But the apparatus which formed the moveable extremity of Struve's rod consisted of a bent lever which turned on an axis passing through the bar, near its extremity, the motion of the short arm of the lever being in the direction of the length of the bar. The short arm terminated in a hemisphere which projected a little beyond the end of the bar ; and in making the contacts, the flat and fixed end of the next bar was pressed against the hemisphere, until an index on the extremity of the long arm of the lever stood at the middle of a scale connected with the bar, in which position the distance between the plane in which the bar terminated at one end, and the apex of the hemisphere at the other end, was exactly two toises at the normal temperature. A steel spring acting on the long arm of the lever regulated the degree of pressure applied in making the contacts.

In measuring the Prussia base Bessel used four compound bars constructed on the same principle as those of Delambre. The apparatus, which is simple and ingenious, will be readily understood from the annexed figure, in which the two ends are shown. $i\,i'$ is a bar of iron two toises in length, an inch broad, and a quarter of an inch thick $z\,z'$ is a bar of zinc of the same thickness and half the breadth. The two bars are firmly connected by screws and soldering at the end $z\,i$. The zinc bar $z\,z'$ terminates in two knife-edges of steel, the edges being horizontal. $k\,k'$ is a part of the iron bar, terminating in knife-edges, which are placed vertically, or at right angles to the former. The length of the measuring bar, or two toises at the normal temperature, is defined by the knife-edges at z and k' ; while the interval between z' and k varies with the temperature, and indicates the relative expansion, from which the absolute expansion of the iron bar becomes known. This interval was measured by inserting a thin glass wedge between the knife-edges ; and when the bars were placed in the line of the base, the interval between the knife-edge k' of one bar and z of the adjacent one was measured in the same manner. By means of fine divisions on the parallel sides of the glass wedges an interval in the direction of the base so small as the 12,000th part of an inch was made visible.

Fig. 1.



For the measurement of the Irish base an apparatus was employed by Colonel Colby in which the expansion of the measuring-rods was compensated in such a manner that no reduction was required on account of variations of temperature. The principle of this very ingenious apparatus will be understood from the following description :—A B is a brass bar, 10 feet in length. C D a bar of iron, firmly connected with the former at the middle E. Two steel tongues A P, B Q, are connected with the extremities of the bars by double conical joints which allow sufficient play to the tongues to prevent interference with the free expansions of the bars. At a certain normal temperature the steel tongues are perpendicular to the direction of the bars. Suppose them in this position, and that an increase of temperature takes place : the brass bar will become longer than the iron bar in consequence of its greater relative expansion, and a straight line A C P (on the middle of the tongue) will come into the position a c P, intersecting its former direction at a point P, so situated that P C has to P A the ratio of the expansion of the iron bar to that of the brass bar. But this ratio being constant, P is a given point ; and as the corresponding point Q on the other tongue is in precisely the same circumstances, it follows that the distance between P and Q will remain unaltered in all temperatures, provided at least both bars have the same temperature. This invariability is, however, not absolute, for when the tongue comes into the oblique position a P is longer than A P, and consequently the point marked on the tongue will be between a and the invariable point. Hence an increase of temperature must increase the distance between

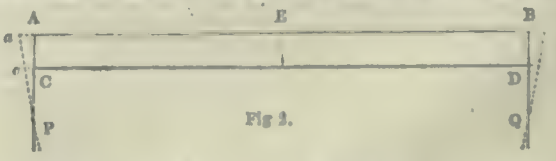


Fig 2.

P and Q: but the effect is insensible. The distance between the two bars was about 2 inches, and the distance of P from the iron bar or P O (which was determined experimentally) about 3½ inches. The bars were enclosed in strong wooden cases, having only the ends of the steel tongues exposed, and the cases laid upon trestles. Five or six sets of bars were used together; and when levelled and adjusted in the line of the base, the interval between the point Q on one set, and the point P on the next, instead of being variable (as in the methods of Delambre and Bessel), was made equal to a given constant quantity. This was effected by means of a microscopic apparatus, constructed on the same principle as the measuring apparatus, two microscopes taking the place of the steel tongues, and their foci being the points whose distance remains invariable. The microscopes were 6 inches apart, and between them, at the same distance from each, was a small telescope invariably connected with the two metallic bars, to which the microscopes were attached; the whole being so disposed that the three optical axes were in the same plane, and parallel to each other at the normal temperature. This apparatus being placed parallel to the line of the base, over the end of one of the sets of measuring bars, in such a manner that the point Q on the steel tongue was bisected by the cross-wires of one of the microscopes, the next set of bars was moved backwards or forwards until the point P was bisected by the cross-wires of the other microscope. A very delicate level fixed on the upper bar of the microscopic apparatus gave the means of adjusting the optical axis of the telescope exactly in the vertical; by which means, when it was necessary to suspend the operations, or to change the level of the line of the base, the point from which the measurement was to be resumed could be determined with much greater precision than by the usual means of a plummet. The measuring-bars were compared (daily, we believe) with a standard iron bar, which therefore is the unit of the distances; and the interval between the foci of the microscopes was in like manner verified by comparison with a scale.

The question of superiority among these different modes of measuring a base must be decided with reference to practical convenience: it cannot be affirmed that the results of any one of them are decidedly more accurate than those of the others. Col. Colby's apparatus is exceedingly beautiful in theory, but the play of the joints by which the tongues are connected with the bars, and the uncertainty there must be about the determination of the invariable points, and that their distance remains unaltered while changes of temperature are taking place, are obvious disadvantages. Bessel's apparatus is the most compact, and in fewest pieces; and we should imagine that his mode of measuring the intervals between the successive bars would be found easier in practice than making the distance between them constant. On the other hand, the adjustment of a point under the focus of a microscope is an operation which can probably be executed with greater precision than the measurement of the distance between two solid bodies, whether by a scale and vernier, according to the method of Delambre, or by a finely-divided wedge, as used by Gauss and Bessel.

The length of the base is a matter of some importance. Theoretically speaking, it cannot be too long. If a distance on the earth's surface (an arc or meridian, for example) deduced from a trigonometrical operation be m times the length of the base, then, putting errors of observations and calculation out of view, the probable error in the distance is to the probable error of the base in the ratio of $\sqrt{m} : 1$; consequently the longer the base the less is the probable error of the result. On the other hand, the probable error in the measurement of the base increases as the square root of its length; so that a distance deduced from a base of three miles measured only once would have as great a probable error as if it had been deduced from a base of only one mile measured three times, and the mean result taken as its true length. The bases measured in connection with the British survey, vary in length from 4·6 miles to about 8 miles. In the Indian survey the bases averaged about 7 miles. The two bases at Melun and Perpignan, on which the great French arc of meridian depends, were both upwards of 7 miles, and each consisted of two parts inclined to each other. In the Irish base 8 miles were directly measured with the compensation bars, and 2 miles were added by triangulation. Struve's base was 2315 toises, or about 2·8 miles. The Prussian base, measured by Bessel, was only 935 toises, or about 1⅛ mile. Baron Zach, who measured some small bases in Italy, contends that long bases, such as were measured in the French, English, and Indian surveys, are attended with no advantages corresponding to the expense they occasion; and Professor Schwerd, in an interesting account of a base of 2818 feet, measured by him near Spire, reasons to the same effect. ('Die Kleine Speyerer Basis,' Speyer, 1822.) Although we cannot subscribe to these opinions, it must be admitted that as instruments and the methods of observing and computing the observations have been improved, the necessity for frequent verification by the measure of new bases has been proportionably diminished.

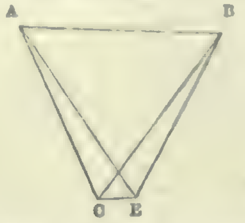
When the measuring-rods have been applied to the whole line of the base, and the proper reductions made for expansion, inclination, &c., the distance is obtained between the terminal points, in terms of the standard to which the measuring-rods are referred, on an arc of a great circle of the earth. In order that the results of different surveys may be comparable with each other, this circle must have a determinate radius; and hence it is usual to substitute for the arc actually measured, the corresponding arc on the surface which coincides with the mean level of the sea. Let l denote the measured length of the base, l' its length reduced to the mean level of the sea, h its height above that level, and r the radius of the earth: the l' is found from this proportion, $r+h : r :: l : l'$.

Triangulation.—In commencing the Triangulation, the first step is to make choice of the points or stations which are to form the summits of the principal triangles. The choice of stations must be determined in some measure by the nature of the country, and with reference to the objects of the survey; but care must be taken to avoid very acute angles, because small errors in the measurement of such angles will give rise to large errors in the lengths of the sides deduced from them. The best-conditioned triangles are those which are nearly equilateral. The principal triangles should be of considerable magnitude, for the probable error of a distance deduced from a base through a series of triangles increases with the number of intermediate triangles. Sides averaging from 20 to 50 miles may be considered as the most convenient; but in mountainous countries, or for connecting stations separated by the sea, the magnitude of the triangles will sometimes be limited only by the distance at which the signals cease to be visible from each other. When the object of the survey is the topography of the country, the geographical positions (the latitudes, longitudes, and altitudes above the sea), as well as the mutual distances of these primary stations, should be determined with all the precision it is possible to attain. The more remarkable features of the country are afterwards connected with the principal stations, by *secondary* triangles, which, being liable only to small relative errors, may be determined more expeditiously by less precise observations or with inferior instruments; and the intermediate points are filled in by means of the surveyor's compass and chain. [SURVEYING.]

Signals.—When the stations have been chosen, the next point to be considered is the erection of signals. In the earlier surveys, the usual practice was to select such conspicuous objects as the country presented, as church spires, windmills, &c.; but experience has shown that objects of this kind, even when found (which will seldom be the case) in those positions where it is desirable that the angular points of the triangles should be established, are not well adapted for signals, and that in general the most advantageous course is to construct them for the express purpose. In the earlier part of the English survey, the observations were chiefly made by night, and the signals were reverberatory lamps with concave metallic reflectors supported by flagstaffs, and enclosed in tin cases, having plates of glass in front to screen the light from the action of the wind. Such signals answer well enough for distances under 30 miles. Biot and Arago, in the prolongation of the French arc of meridian, also employed reverberatory lamps and concave reflectors; and in one case the distance between the station and the signal exceeded 100 miles. Bengal lights, blue-lights, and other contrivances have also been used as night-signals. Delambre constructed his signals of wood in the form of truncated four-sided pyramids, and observed by day. For the large triangles in Ireland and the west of Scotland, Colonel Colby built up conical piles of dry stone, which were thrown down when the instrument was taken to the spot, and again built up when it was necessary to observe the same signal from other stations. Such signals were found to be visible in the telescope of the great theodolite at the distance of 90 or 100 miles in favourable weather. Plates of polished metal, placed so as to reflect the light of the sun in the proper direction, have been found a powerful means of rendering a station visible. Gauss proposed the heliotrope, in which the reflecting surface is silvered glass; and this was the signal which was principally used by Struve and Bessel. Another method, adopted by Bessel for short distances, was the reflexion of light from a hemisphere of polished copper. These two last methods have the disadvantage of rendering the observer dependent on sunshine, but in other respects they afford excellent signals, for as the light proceeds from a point, the observation is made with the greatest precision. In the case of the hemisphere indeed, the luminous point is not in the axis of the signal, but as the radius of the hemisphere and the azimuth of the sun at the time of the observation are known, its position with reference to the axis can be accurately computed, and a correction applied if the deviation is sensible. But all solid bodies used as signals render a similar correction necessary when the light falls upon them obliquely. To avoid this inconvenience, Svanberg observed the light of the sky through a rectangular opening in a blackened board which turned about a vertical axis, so that its plane could always be placed perpendicular to the visual ray. Night-signals are found inconvenient by reason of the unsteadiness and the scintillations of the light; and accordingly geodetical observations are now generally made by day; nevertheless, under peculiar circumstances, night observations may be advantageous, or even necessary. Thus, in India, Colonel Everest found that the greater refraction during the night sometimes rendered stations visible which could not be seen by day, being hid by the intervening ground.

With respect to instruments and the methods of observing in geodetical surveys, ample information is given in the articles THEODOLITE, REPEATING CIRCLE, &c. We may here remark, however, that as each signal (speaking generally) is the common vertex of several triangles, an angle required for the calculation of a triangle may frequently be obtained from the sum or difference of other angles at the same point, as well as by direct observation. This circumstance permits the observations to be made in various ways, and affords an important means of verification; but in order that full advantage may be derived from it, the observations must be made and combined according to some systematic plan. Struve, in the Russian triangulation, adopted the plan of observing successively the direction of every signal visible from his station, in reference to a certain arbitrary direction; and the same method was followed by Bessel. This appears to be the mode of conducting the observations by which an observer is enabled to make the most of his position.

Reduction to the Centre of the Station.—It is desirable that the centre of the instrument should always be placed in the vertical line which coincides with the axis of the signal at the same station; but the strict fulfilment of this condition may sometimes be impossible, or at least extremely inconvenient. In such cases the instrument is placed near the station, and a correction made for the excentricity. Let C be the centre of the station, E the place where the instrument is placed, A and B the distant signals, so that ACB is the angle which is required, and AEB the angle actually measured. Let the distance CE be denoted by d, and AC (computed approximately) by m; then the difference, in seconds, between ACB and AEB is found from this formula—



$$ACB - AEB = \omega\, d \sin(BAC - BEC) \div m \sin BAC,$$

where $\omega = 206264{\cdot}8''$, the number of seconds in an arc equal to the radius, or $\omega = \operatorname{cosec} 1'' = 1 \div \sin 1''$.

Reduction to the Horizon.—Although the theodolite has now come into general, perhaps universal use, in carrying on important geodetical operations, we shall add the formula by which an angle measured in the oblique plane passing through the instrument and the two observed objects is reduced to the horizon. Let A and B be the remote signals, C the angle in the oblique plane, C′ its projection on the plane of the horizon; and let α and β denote respectively the number of seconds by which A and B are observed to be elevated or depressed above or below the horizon of C; then

$$C - C' = \left\{ \tfrac{1}{4} (\alpha+\beta)^2 \tan \tfrac{1}{2} C - \tfrac{1}{4} (\alpha-\beta)^2 \cot \tfrac{1}{2} C \right\} \sin 1''.$$

When the angles have been measured, and (if necessary) deduced to the centre of the station and the horizon, their values as given by the instrument, being all affected with some portion of error which it is impossible by any means to get rid of, must undergo a process of correction or adjustment, or be made to satisfy certain mathematical conditions, before a determinate result can be deduced from them. In order to establish these conditions the following quantity must be computed for every triangle in the series.

Spherical Excess.—The spherical excess of a triangle on the surface of a sphere or spheroid, formed by the sections of planes perpendicular to the surfaces, is the excess of the sum of its three angles over 180°. This excess has a given relation to the area of the triangle depending upon the radius of the sphere; and in a geodetical survey the data for computing it are, in every case, a side c, and the three observed angles A, B, C, of which C is supposed opposite to c. Let S denote the number of square feet in the surface or area of the triangle, E the spherical excess in seconds, and r the radius of curvature in feet; we have then $S = \frac{1}{2} cc \sin A \sin B \div \sin C$, and $E = \omega S \div rr$, where $\omega = 206264{\cdot}8''$.

On the spheroid, the radius of curvature of a section perpendicular to the surface is variable, and depends both on the latitude and the inclination of the section to the meridian. For a series of triangles included between two parallels of latitude whose distance is not more than two or three degrees, r may be supposed constant in computing the spherical excess; and as the nearest approximation to its mean value, we may take the radius of curvature of the section which intersects the meridian in an angle of 45°, at the middle latitude. The general formula for the radius of curvature of an oblique section is

$$\frac{1}{r} = \frac{(1 - ee + ee \cos^2 l \cos^2 \theta) \sqrt{(1 - ee \sin^2 l)}}{a(1 - ee)}$$

where a is the radius of the equator, e the excentricity (so that $ee = (aa - bb) \div aa$, b being half the polar axis), l the latitude, and θ the azimuth, or inclination of the section to the meridian.

Let ρ denote the radius of curvature of the meridian (for which $\theta = 0$), ρ' that of the section perpendicular to the meridian (for which $\theta = 90°$), the formula gives

$$\frac{1}{\rho} = \frac{\sqrt{(1 - ee \sin^2 l)^3}}{a(1 - ee)}; \quad \frac{1}{\rho'} = \frac{\sqrt{(1 - ee \sin^2 l)}}{a};$$

whence also

$$\frac{1}{r} = \frac{1}{\rho} \cos^2\theta + \frac{1}{\rho'} \sin^2\theta = \tfrac{1}{2}\left(\frac{1}{\rho} + \frac{1}{\rho'}\right) + \tfrac{1}{2}\left(\frac{1}{\rho} - \frac{1}{\rho'}\right) \cos 2\theta,$$

from which $1 \div r$ is readily computed for any value of θ. When $\theta = 45°$, the second term vanishes.

In the latitude of Greenwich (51° 28′ 39″), $\rho = 20911961$ feet, $\rho' = 20966473$ feet, whence (making $\theta = 45°$) $\log (\omega \div rr) = 0{\cdot}67251 - 10$, and consequently $\log E = \log S + 0{\cdot}67251 - 10$. In order that E may amount to 1″, we must have $\log S = 9{\cdot}39749$, or $S = 2{,}497{,}800{,}000$ square feet, or nearly 76½ square miles, that is to say, the spherical excess amounts to 1″ for every 76½ square miles in the area of the triangle. The calculation of the area therefore does not require to be made with much accuracy, and may be facilitated by means of subsidiary tables.

Correction of the Observations.—One of the improvements for which practical geodesy has recently been indebted to the German astronomers, particularly Gauss and Bessel, is a general method of combining and correcting the observations according to the principles of the theory of probability, so as to elicit the result which is *most probably* nearest the truth, or which gives the nearest representation of the whole of the observations. Formerly the practice was to regard each triangle as a complete and independent whole, and to adjust the observed angles (usually by some arbitrary process, or according to the observer's judgment of their relative goodness), so as to fulfil the condition of their sum being equal to 180° together with the spherical excess, without regard to the relations subsisting among the angles of the quadrilaterals or other polygons formed by the lines connecting the angular points. But this mode of proceeding affords a very imperfect solution of the problem: for in order to obtain the best result which can be deduced from the observations, it is indispensable to have regard not only to the condition just named, but to every independent relation subsisting among the angles of the whole series of triangles included in the survey; and the more numerous the relations are which the observations are made to satisfy, the greater will be the probable accuracy of the final result.

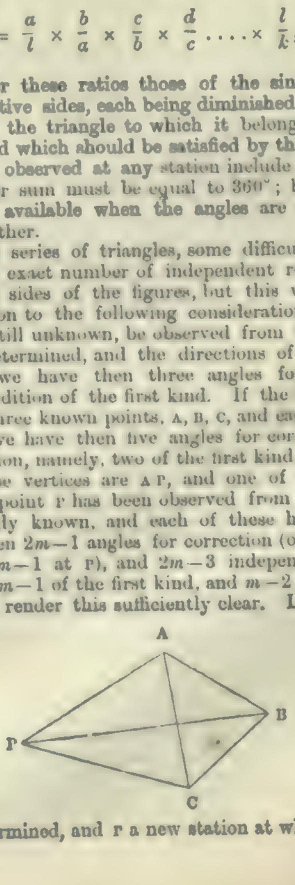
The equations of condition which express the independent relations connecting the angles of a system of geodetical triangles arise chiefly from three sources: 1, The sum of the three angles of each triangle is equal to 180° *plus* the spherical excess; which excess, being in all cases a very small quantity, can be computed to so great a degree of accuracy, that it may be regarded as absolutely exact. 2, If there be a system of triangles so connected that the second has a side a in common with the first, the third a side b in common with the second, the fourth a side c in common with the third, and so on to the last, which has a side k in common with the preceding one, and another side l in common with the first, then, on forming the identical equation

$$1 = \frac{a}{l} \times \frac{b}{a} \times \frac{c}{b} \times \frac{d}{c} \cdots\cdots \times \frac{l}{k},$$

and substituting for these ratios those of the sines of the angles opposite the respective sides, each being diminished by a third of the spherical excess of the triangle to which it belongs, an equation of condition is obtained which should be satisfied by the observed angles. 3, When the angles observed at any station include the whole circuit of the horizon, their sum must be equal to 360°; but this condition can only be made available when the angles are determined independently of each other.

In a complicated series of triangles, some difficulty may be found in determining the exact number of independent relations furnished by the angles and sides of the figures, but this will be materially lessened by attention to the following considerations: If a point, P, whose position is still unknown, be observed from two other points, A and B, already determined, and the directions of A and B be also observed from P, we have then three angles for correction, and one equation of condition of the first kind. If the unknown point, P, be observed from three known points, A, B, C, and each of these be also observed from P, we have then five angles for correction, and three equations of condition, namely, two of the first kind, furnished by the two triangles whose vertices are AP, and one of the second: and, generally, when a point P has been observed from m stations whose positions are already known, and each of these has been observed from P, we have then $2m-1$ angles for correction (one at each of the given points and $m-1$ at P), and $2m-3$ independent equations of condition, namely, $m-1$ of the first kind, and $m-2$ of the second.

An example will render this sufficiently clear. Let A, B, C be three points already determined, and P a new station at which the directions



of A, B, and C have been observed, and which has itself been observed from those points. These observations give five independent angles to be corrected, namely, two at P, and one at each of the other stations, and three equations of condition, which are thus found: the two triangles APC and BPC give two equations of the first kind, namely,

$$1,\ \mathrm{APC}+\mathrm{PAC}+\mathrm{ACP}=180^\circ+\mathrm{E},$$
$$2,\ \mathrm{BPC}+\mathrm{PBC}+\mathrm{BCP}=180^\circ+\mathrm{E}'.$$

On considering the three triangles APB, BPC, ABC, it will be seen that the side PB is common to the first and second, BC to the second and third, and AB to the third and first. Forming therefore the identical equation

$$1=\frac{\mathrm{PB}}{\mathrm{AB}}\cdot\frac{\mathrm{BC}}{\mathrm{PB}}\cdot\frac{\mathrm{AB}}{\mathrm{BC}},$$

and substituting for those ratios those of the sines of the opposite angles (each diminished by one-third of the spherical excess), we get the equation of the second kind:—

$$3,\ 1=\frac{\sin\mathrm{PAB}}{\sin\mathrm{APB}}\cdot\frac{\sin\mathrm{BPC}}{\sin\mathrm{BCP}}\cdot\frac{\sin\mathrm{ACB}}{\sin\mathrm{CAB}}.$$

When the equations of condition have been thus formed, the observed values of the different angles are substituted in them, each being increased or diminished by a small indeterminate correction. The values of the corrections are then determined simultaneously by solving the equations according to the method of *minimum squares*, or so that the equations of condition shall be satisfied as nearly as possible (they cannot be all satisfied exactly), and the sum of the squares of the corrections shall be a minimum. For further details on this subject, and examples of the application of the theory to trigonometrical surveys, we must content ourselves with a reference to the 'Supplementum Theoriæ Combinationis,' &c. of Gauss (Göttingen, 1828), where it is applied to a portion of the triangles surveyed by Krayenhoff in Holland; to Nos. 121 and 122 of the 'Astron. Nachrichten,' where it is applied by Rosenberger to Maupertuis's measurement in Sweden; to No. 438 of the same work, where it is applied by Bessel to the computation of the triangles at the southern extremity of the French arc of meridian: and to the 'Gradmessung in Ost-Preussen,' already referred to. The advantages of the method are two-fold. In the first place there is the probability that the result is *nearer* the truth than if it had been deduced in any other way; and secondly, a general and uniform process of calculation is substituted for an imperfect and arbitrary one.

In proceeding according to the ordinary method, and regarding the triangles as independent of each other, the process is much simpler. The difference between the sum of the three observed angles and 180° + E is the aggregate error of the three determinations. If each angle was determined by an equal number of equally good observations, the probable error would be the same for each, and the correction would be properly made by dividing the aggregate error equally among the three. If the observations are assumed to be equally good, but each of the angles has been determined by a different number, then the portion of the aggregate error which should be thrown upon each angle is reciprocally proportional to the number of observations by which it was determined; but when the individual observations are not equally good (and this is the general case) the distribution of the aggregate error should be made in such a manner that the amount of the correction to be applied to each angle is proportional directly to the sum of the squares of the differences between each observation and the arithmetical mean of the whole, and inversely as the square of the number of observations by which the angle was determined. If an angle has been determined by a single reading, the portion of the aggregate error to be assigned to it may be made proportional to the *mean square* (that is, the sum of the squares of the differences from the mean divided by the number of observations) of the errors of a series of observations at one of the other angles made under similar atmospheric circumstances. Such is the method which the theory of probable errors indicates; but in most of the geodetical surveys which have yet been published, the distribution of the aggregate error among the three angles has been made, as already remarked, according to some arbitrary hypothesis.

The three angles of the triangle, corrected in the manner now described, are regarded as the true geodetical angles, or rather as the spherical angles formed by the arcs of the great circles which intersect in the verticals passing through the stations on the surface of the osculating sphere. In strictness there are no practical means of determining the true geodetical angles, that is, the angles made by the shortest lines on the spheroid. The observed angle is not the geodetical angle, but the angle made by the two planes which intersect in the vertical of the station, and pass through the remote signals.

Calculation of the Sides.—The method of computing the sides which first suggests itself is, to convert the given or known side into degrees of a circular arc, whose radius is equal to that of the earth, and apply the formulæ of spherical trigonometry. This method has been sometimes adopted; but as it gives rise to tedious calculations, it is usual to have recourse to more expeditious processes, which, though only approximative, give equally exact results. Various methods of approximation have been proposed, though there are only two which have been much used. One of them is the method which has been exclusively followed in the Ordnance survey, so far as published, and also, generally by Delambre. It consists in deducing from the spherical angles the corresponding angles formed by the chords, and then computing the triangle by plane trigonometry. In this manner the chords of the two unknown sides are found, from which the sides themselves are easily deduced. The formulæ are as follows:—

Let the three spherical angles (that is, the observed angles corrected for the errors of observation) be denoted by A, B, C; the sides respectively opposite by a, b, c (expressed in feet); and the radius of curvature of the surface by r (also in feet). Let A′ be the angle formed by the chords of the sides b and c, and suppose $\mathrm{A}-\mathrm{A}'=x$ seconds; then putting $\omega=206264{\cdot}8''$,

$$x=\frac{\omega}{16}\left(\frac{b+c}{r}\right)^2\tan\tfrac{1}{2}\mathrm{A}-\frac{\omega}{16}\left(\frac{b-c}{r}\right)^2\cot\tfrac{1}{2}\mathrm{A}.$$

In like manner if B′ and C′ denote the chord angles corresponding to the spherical angles B, C, respectively, and if we suppose $\mathrm{B}-\mathrm{B}'=x'$ and $\mathrm{C}-\mathrm{C}'=x''$, the two small corrections x' and x'' will be computed from similar expressions to the above, and we have then the three plane angles A′, B′, C′, the sum of which is 180°. For computing these corrections approximate values of the sides must be previously found; but for this purpose it will generally be sufficient to use logarithms to four decimal places.

Although for facility of explanation we have described the reduction to the chord angles as applied to the corrected spherical angles, it is manifest that it may be (in practice it generally is) applied to the observed angles. In this case we get $\mathrm{A}'+\mathrm{B}'+\mathrm{C}'=180^\circ\pm$ the aggregate error of the three observed angles, which error must be then distributed among the three reduced or chord angles in the manner before described, so that their sum may be exactly 180°. By this means, since we have obviously $x+x'+x''=\mathrm{E}$, the previous calculation of the spherical excess, in order to correct the observations, is rendered unnecessary.

When the chords have been computed from the reduced angles A′ B′, C′, the arcs are found in terms of the chords by a well-known series, of which it is only necessary to use the two first terms. Let a be a small arc, and a' its chord, then $a=a'-(a'^3\div 24r^2)$.

The other method of computing the sides to which we have alluded depends on the following theorem, which was first given by Legendre. If from each of the angles of a spherical (or spheroidical) triangle, the sides of which are small in comparison of the radius, one-third of the spherical excess be deducted, the sines of the angles thus diminished will be proportional to the lengths of the opposite sides, so that the triangle may be computed as in plane trigonometry. As before, let A B, C be the corrected spherical angles, a, b, c the sides respectively opposite, and E the spherical excess; then, if we make

$$\mathrm{A}'=\mathrm{A}-\tfrac{1}{3}\mathrm{E},\ \mathrm{B}'=\mathrm{B}-\tfrac{1}{3}\mathrm{E},\ \mathrm{C}'=\mathrm{C}-\tfrac{1}{3}\mathrm{E},$$

we shall have, in virtue of the theorem,

$$b=\frac{a\sin\mathrm{B}'}{\sin\mathrm{A}'},\ c=\frac{a\sin\mathrm{C}'}{\sin\mathrm{A}'},$$

from which formulæ the sides b and c are computed. This method therefore requires no greater amount of calculation than would be necessary if the triangles were on a plane surface, excepting that of the spherical excess; and if the three angles are assumed to be determined with equal accuracy, even this is not wanted (unless for the purpose of testing the accuracy of the observations), the angles for calculations being found at once by applying to each of the three observed angles a third of the difference between their sum and 180°. This is the method which is most frequently adopted.

Legendre's theorem will give a sufficiently accurate result in ordinary cases; but if the triangles are very large, and the utmost precision is aimed at, it will sometimes be desirable to have a closer approximation. This may be obtained by computing the angles A′, B′, C′ from the following expressions of their values, which appear to have been first given by Professor Buzengeiger, in Lindenau's 'Zeitschrift für Astronomie,' vol. vi. (Tübingen, 1818), and which are equivalent to an extension of the theorem so as to include terms of the second order, Legendre's approximation including only those of the first. As before, let S be the area of the triangle, and $\omega=206264''{\cdot}8$, then

$$\mathrm{A}-\mathrm{A}'=\frac{\omega\mathrm{S}}{3rr}\left(1+\frac{aa+7bb+7cc}{120rr}\right),$$
$$\mathrm{B}-\mathrm{B}'=\frac{\omega\mathrm{S}}{3rr}\left(1+\frac{7aa+bb+7cc}{120rr}\right),$$
$$\mathrm{C}-\mathrm{C}'=\frac{\omega\mathrm{S}}{3rr}\left(1+\frac{7aa+7bb+cc}{120rr}\right),$$

and in consequence of these, the spherical excess $\mathrm{E}\,(=\mathrm{A}+\mathrm{B}+\mathrm{C}-180^\circ)$ becomes

$$\mathrm{E}=\frac{\omega\mathrm{S}}{rr}\left(1+\frac{aa+bb+cc}{24rr}\right).$$

It is easy to see that the second terms of these expressions must always be very small; in fact, they will amount only to a few hundredths of a second even in the largest triangles. Nevertheless when the angles are considered as having a mutual dependence, and the corrections for a whole series are determined simultaneously from the equations of condition, the corrected angles will be given (if great precision is required) to three or four decimals of a second, and the above formulæ will have a practical application. They were used by Bessel in the recalculation of the triangles at the southern extremity of the French arc of meridian; and we give them a place the more willingly as they have not hitherto, so far as we know, found their way into any English work.

Professor Buzengeiger has also given a formula for the calculation of the sides of a geodetical triangle, which may be substituted for the method of Legendre, or used for verification. Let a be the known side, A, B, C, the corrected spherical angles, $m = 0{\cdot}4342945$, the modulus of the common logarithms, and $n = m \div 3\omega = 0{\cdot}0000007$, then for computing b and c we have

$$\log b = \log a + \log \sin \mathrm{B} - \log \sin \mathrm{A} + n\,\mathrm{E}\,(\cot \mathrm{A} - \cot \mathrm{B});$$
$$\log c = \log a + \log \sin \mathrm{C} - \log \sin \mathrm{A} + n\,\mathrm{E}\,(\cot \mathrm{A} - \cot \mathrm{C}).$$

With the help of a small table of natural tangents, this method is scarcely more troublesome than Legendre's. The chord method is more tedious than either, and does not appear to be attended with any corresponding advantage.

Latitudes, Longitudes, and Azimuth.—Having ascertained the terrestrial distances between the several stations, the next step is to determine their geographical positions, or situations with respect to the equator and an assumed first meridian. For this purpose the latitude and longitude of one station at least, and the azimuth of a side of one of the triangles, must be accurately determined by astronomical means; we have then the data that are necessary for computing the geographical position of every other angular point, and the bearing of every other side, through the whole series of triangles, assuming the earth to be a spheroid of rotation of known dimensions and ellipticity. The uncertainty, however, which always exists respecting the exact form and curvature of any particular portion of the earth's surface, or rather the irregularities of local configuration, require independent astronomical observations, particularly of azimuth, to be made at more stations than one, when the triangulation extends over a considerable tract of country.

If the country included in the survey contains a fixed observatory, this will of course either form one of the principal stations or be connected with the principal triangles, and may be taken as the point of departure. In this case the astronomical position of the fundamental point is known with the greatest certainty; and the meridian-mark of the transit-instrument affords the surest means of determining the bearing of any signal visible from the observatory. At any other station the best method of determining the azimuth is probably to imitate this proceeding, by setting up a temporary mark as nearly in the meridian as may be, and determining its deviation with a transit-instrument by some of the methods used in practical astronomy for the purpose. [TRANSIT-INSTRUMENT.] The angle between the mark and the signal at another of the principal stations is then measured with the theodolite, whence the azimuth of the signal becomes known. But as this method cannot always be conveniently followed in geodetical operations, the usual practice is to make the surveying instrument itself subservient to the determination of azimuths. In the English survey the method commonly adopted was, to observe with the theodolite the angle between a flag-staff and the pole-star at its extreme digressions east and west, and to take half the sum of the two angles as the azimuth of the staff. In determining the azimuth in this way a very accurate adjustment of the instrument is necessary. The method usually followed on the Continent has been to observe the angle between a referring signal and the sun, or some star whose place is well known, when near the horizon; and as the azimuth of the sun or star at a given instant of time can be computed with great precision, the observation is liable to no particular cause of error, unless in the determination of the exact clock-time. The result is usually made to depend on the mean of a great number of observations.

The problem on the solution of which the calculation of the geodetical latitudes and longitudes of the stations, and the azimuths of the sides of the triangles, depends is this: Let A and B be two stations whose distance has been determined, and suppose the latitude and longitude of A to be known, together with the azimuth of B as seen from A; it is required to find the latitude and longitude of B, together with the azimuth of A as seen from B. The azimuthal angles are supposed to commence at the south point of the horizon, and to be reckoned towards the west (or right) from 0 to 360°. Assume

l = the latitude of A, l' = the latitude of B,
λ = the longitude of A, λ' = the longitude of B,
θ = the azimuth of AB at the station A,
θ' = the azimuth of AB at the station B,
d = the distance on the spheroid between A and B, in feet.

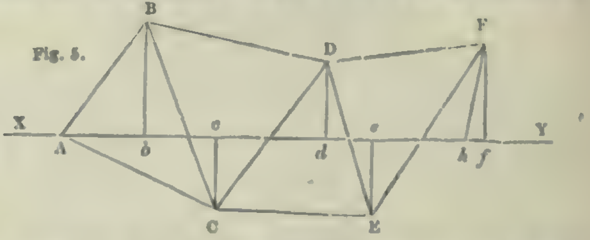
And, as before, let a denote half the greater axis of the meridian, e the excentricity, $\rho' = a \div \sqrt{(1 - ee \sin^2 l)}$, the radius of curvature of the arc perpendicular to the meridian at A, and $\omega = 206264''{\cdot}8$. Then, putting (for brevity) $u = d \div \rho'$, the differences of the latitudes, longitudes, and azimuths of the two stations, in seconds of arc, are given by the following formulæ, namely:—

$$l' - l = -\omega\,(u \cos\theta - \tfrac{1}{2}\,u^2 \sin^2\theta \tan l)\,(1 + ee \cos^2 l),$$
$$\lambda' - \lambda = \omega\,u \sin\theta \sec l',$$
$$\theta' - \theta = 180^\circ - (\lambda' - \lambda) \sin\tfrac{1}{2}(l' + l) \sec\tfrac{1}{2}(l' - l).$$

These formulæ are only approximative; but they are sufficiently exact for every case that can arise in practical geodesy. Even in the case of the greatest distances between the stations, 100 miles for example, the results which they give will agree with those which are computed from the exact formulæ of spheroidical trigonometry to within a small fraction of a second.

By means of the above formulæ, the geographical positions of the principal stations are successively deduced from each other; but when a chain of triangles runs nearly north and south, or east and west, the differences of latitude and longitude are more readily computed by referring the different stations to an assumed meridian by means of parallels and perpendiculars. Let A, B, C, D, E, F be the summits of a chain of triangles, and X Y the direction of the meridian passing through the first point A; and let perpendiculars Bb, Cc, &c., be drawn from each of the other points to X Y. Suppose the angle XAB (the azimuth of B on the horizon of A) to be determined by astronomical observations: then, as the angles at B, C, D, &c., are all known from the geodetical observations, the angles which the several sides of the triangles make with X Y are easily computed; and the distance on the meridian between the perpendiculars through the extremities of any side is found by multiplying the length of the side into the cosine of its inclination. Hence the distance on the meridian from the point of departure A, to the foot of the perpendicular through any other point, F, is equal to the sum of the sides which join A and F, each multiplied into the cosine of its inclination. Thus, the sum of the products of the three sides AB, BD, DF, by the cosines of their respective inclinations, gives Ab + $b$$d$ + $d$$f$ = Af; or the sides AC, CE, EF, reduced in the same manner, give Ac + $c$$e$ + $e$$f$ = Af. Hence the distance from A to the foot of the perpendicular through each point becomes known. In like manner, on multiplying the length of any side into the *sine* of its inclination, we have the difference of the distances of its two extremities from X Y, and the distance Ff, of any point F, is the sum of those differences (taken with their proper signs) in respect of all the intermediate sides between A and F. These relations are more shortly expressed by algebraic formulæ. Let the inclinations of three sides intermediate between A and F, for example, AB, BD, DF (the angles at the different points being all reckoned in the same direction), be respectively α, β, γ; then, attention being given to the algebraic signs of the trigonometrical lines, we have

Fig. 5.



$$\mathrm{A}f = \mathrm{AB}\cos\alpha + \mathrm{BD}\cos\beta + \mathrm{DF}\cos\gamma,$$
$$\mathrm{F}f = \mathrm{AB}\sin\alpha + \mathrm{BD}\sin\beta + \mathrm{DF}\sin\gamma.$$

By this means, all the angular points of the series are referred to the meridian of the first, exactly in the same manner as the different points of a curve are referred to its axis by their co-ordinates.

We have now to determine the differences of latitude. Taking the point F for example, let Fh be the arc of the parallel circle on the spheroid, passing through F, and h its intersection with the meridian of A, then Ah (which is always less than Af) is the arc of meridian corresponding to the difference of latitudes. To compute fh we have, from the properties of the spheroid, the formula $fh = \overline{\mathrm{F}f}^2 \tan l' \div 2\mathrm{R}$, in which l' is the approximate latitude of F, and R the distance from the centre of the earth; and as fh is always very small, instead of computing the value of R, it will be sufficiently accurate to use ρ, the radius of curvature of the meridian corresponding to the latitude. The distance fh thus found is expressed in feet; to convert it into seconds of arc we must multiply by $\omega \div \rho$; hence the difference of the latitudes of F and A, expressed in seconds, is—

$$l' - l = (\omega \div \rho)\;(\mathrm{A}f - fh).$$

The latitude of F and its distance Ff from the meridian of A being known, its longitude, or the arc Fh of the parallel circle, is found from the formula already given. Let ρ' be the radius of curvature of the perpendicular arc Ff, then $(\omega \div \rho')\,\mathrm{F}f$ is the number of seconds in Ff, and hence the difference of longitudes of F and A in seconds is—

$$\lambda' - \lambda = (\omega \div \rho') \times \mathrm{F}f \sec l'.$$

When the positions of a considerable number of points are to be determined, the calculations may be facilitated by forming a table of the values of fh corresponding to every value of Ff proceeding by small differences, 100 feet for example. In following this method, however, the stations must not be so far from the assumed meridian that the difference of the curvilinear distance and its projection on the horizontal plane becomes sensible, and hence in the survey of a large country the direction of a new meridian (or the azimuths) requires to be determined astronomically when the triangulation has been carried a degree or two to the east or west of the point of departure. It is scarcely necessary to add that the positions of the secondary points are computed without reference to the curvature, or convergence of meridians.

The method of computing the distance between the parallels of two remote stations, A and F, which we have now described, is that which is usually followed in measuring arcs of meridian. To this purpose, indeed, it is particularly adapted, for as the chain of triangles runs along the direction of the meridian, the distances of the signals from the line to be measured are not so great as to give rise to any error by reason of the neglect of the curvature of the perpendicular arc. For other methods of computing the parts of the meridian, and formulæ, theoretically more exact, for computing the latitudes, longitudes, and azimuths, see Delambre's 'Méthodes Analytiques pour la Determination d'un Arc du Méridien;' or Puissant, 'Traité de Géodésie,' third edition, 1842.

If the earth were a regular spheroid of rotation, the latitudes and longitudes deduced from geodetical measurements commencing with a given observatory would agree exactly (supposing no errors) with those given by astronomical observations. Such agreement however is not found to exist, and no regular figure can be assigned to the earth by which the results of the two methods can be entirely reconciled. An instance or two will suffice to give an idea of the extent to which the discordances may reach. In the remeasurement of Beccaria's arc, the astronomical difference of latitude between Andrate and Mondovi was found to be 1° 7′ 26″.98, while the difference computed from the French triangulation, taking the observatory of Paris as the point of departure, and assuming the ellipticity $=1 \div 308{\cdot}65$, was 1° 8′ 14″.82. The discordance amounts to 47″.84, corresponding to a distance on the meridian of about 4880 English feet, the whole distance being about 368,885 feet. Again, the latitude of Venice deduced from that of Rimini by triangulation was found to differ 17″.2 from the latitude given by direct observation; and the latitude of Rimini deduced from that of Milan differed 27″.4 from the astronomical latitude. ('Connaissance des Tems,' 1827.) Similar anomalies have been found in the surveys in England, France, Austria, and indeed all other countries; and as their amount exceeds that which can with any probability be assigned to errors of observation, they are ascribed to irregularities in the direction of gravity arising from inequalities in the form or internal structure of the earth,—to the attraction of mountains or local variations of density. Puissant ('Mém de l'Acad.,' t. xiv., 1838) shows reason for supposing that in France the curvature of the surface is considerably different on the east and west sides of the meridian of Paris.

Determination of the Altitudes.—In order to complete the description of the objects embraced in a trigonometrical survey, it only remains for us to point out the manner in which the relative heights of the stations are observed and computed. The observations required for this purpose are the zenith distances of the signals as seen from each other; and they may be made with the theodolite or any instrument with which angles can be measured in a vertical plane. The chief difficulty attending the determination arises from the uncertainty of the terrestrial refraction, an element which is liable to frequent and considerable variations, more especially as the objects observed are always nearer the horizon. The formulæ are as follows:—

Let h and h' denote respectively the heights of two stations, A and B, above the level of the sea; z the zenith distance of B as observed at A; Δz the seconds of arc through which B is elevated by the refraction; z' and $\Delta z'$, the corresponding quantities in respect of A as observed at B; C the angle at the centre of the earth formed by the verticals of A and B; d the distance in feet between A and B on the spheroid; and r the radius of curvature of the terrestrial arc. The plane triangle formed by the two verticals and the straight line which joins A and B gives this analogy:—

$$2r+h'+h : h'-h :: \cot \tfrac{1}{2} C : \tan \tfrac{1}{2} \left\{z'+\Delta z'-(z+\Delta z)\right\},$$

from which, on rejecting superfluous quantities, and with the aid of certain physical assumptions, the formulæ for computation are deduced.

In the first place, $h'+h$ may be rejected as being insensible in comparison of $2r$: then since $z'+\Delta z'-(z+\Delta z)=2\left\{90°-(z+\Delta z-\tfrac{1}{2}C)\right\}$, the above analogy gives

$$h'-h=2r \tan \tfrac{1}{2} C \cot (z+\Delta z-\tfrac{1}{2}C).$$

Again, because C is always a very small angle, we may put, without sensible error, $d=2r \tan \tfrac{1}{2} C$. The last formula then becomes

$$h'-h=d \cot (z+\Delta z-\tfrac{1}{2} C).$$

With respect to the unknown quantity Δz, two assumptions are made: first, it is assumed that the whole effect of the refraction at both stations is proportional to the distance between the stations, or to the angle C; or to assume $\Delta z'+\Delta z=kC$, where k is a numerical coefficient. Secondly, it is assumed that the effect of the refraction is the same at both stations, or that $\Delta z'=\Delta z$; this gives $\Delta z=\tfrac{1}{2}kC$, and consequently $\Delta z-\tfrac{1}{2} C=-\tfrac{1}{2}(1-k) C$. Substituting this in the last equation, we get

$$h'-h=d \cot \left\{z-\tfrac{1}{2}(1-k) C\right\} \qquad (a).$$

This equation gives the height of the signal at B above the place of the instrument at A in terms of the geodetical distance d, and the observed angle z, assuming the coefficient of refraction to be known. It will be observed that C is given in seconds by the formula $C=\omega d \div r$, where $\omega=206264''{\cdot}8$.

When the zenith distances are observed at both stations, the coefficient k may be deduced from the observations; for the assumption of $\Delta z'+\Delta z=k C$ gives $kC=C+180°-(z+z)$, whence

$$1-k=(z'+z-180°) \div C. \qquad (b).$$

A mean value of k, deduced in this manner from a number of reciprocal observations, may be substituted in the equation (a) for finding the difference of the heights of two stations when the zenith distance has been observed at one of them only. But when z' and z are both observed, the difference of altitude is obtained independently of the value of k; for on substituting the value now given of $1-k$ in equation (a), we get

$$h'-h=d \tan \tfrac{1}{2}(z'-z). \qquad (c).$$

The absolute height h of the first station is usually found by levelling from the surface of the sea at half-tide. But assuming the refraction to be known, the absolute height of a station may be determined by observation of the zenith distance of the sea horizon. The formula is

$$h=\tfrac{1}{2} r (1+\tfrac{1}{2}k)^2 \tan^2 (z-90°). \qquad (d).$$

In the application of the preceding formulæ, it is necessary to attend to the height at which the instrument was placed with respect to the signal, or point for which the calculation is to be made. For instance, if the object observed is the surface of the ground, and the instrument is placed at the height of n feet above the surface at both stations, then on computing the coefficient of refraction from the formula (b), the angles z' and z must be each diminished by the number of seconds in the angle subtended by n feet at the distance d, that is, by $206264''{\cdot}8\ n \div d$. In the formula ($c$), which applies to reciprocal observations, the height of the instrument need not be regarded, provided it be the same with respect to the signal at both stations. In the cases to which (a) and (d) apply, the correction is made by subtracting the height of the instrument above the ground from the results given immediately by the formulæ.

The surest determination of altitudes is that which is given by reciprocal observations; for in this case the only assumption involved in the formula is, that the refraction is the same at both stations; and if the observations are made under similar atmospheric circumstances, this cannot well be supposed to lead to error. Such observations also give a more certain value of the coefficient of refraction than can be deduced from the astronomical theory, which, besides the hypotheses necessary for connecting the variation of temperature with the altitude, assumes also (for the present purpose) that the variation of temperature follows the same law throughout the whole distance from the one station to the other. The mean value of k, deduced by Bessel from reciprocal observations made during the measurement of the Prussian arc, was 0·1370; Gauss found 0·1306; Caraboeuf, from the French triangulation in Piedmont, 0·1285: Struve, in Russia, 0·1237; Delambre and Méchain, 0·1566; and in the English survey the definitive value of k was found to be 0·0809 for rays crossing the sea, and 0·0750 for rays not crossing the sea.

We shall conclude this article with a short statement of some of the more important results relative to the figure and dimensions of the earth which have been deduced in recent years from a discussion of arcs of the meridian and of parallel.

In the 'Encyclopædia Metropolitana' (art. 'Figure of the Earth'), Mr. Airy has discussed fourteen arcs of the meridian and four arcs of parallel. The results obtained by him are—

$$a=20{,}923{,}713 \text{ feet.}$$
$$b=20{,}853{,}810 \quad ,,$$
$$\epsilon=\frac{a-b}{a}=\frac{1}{299{\cdot}33} \text{ feet,}$$

a, b, denoting the semi-major and semi-minor axes of the terrestrial spheroid, and ϵ the ellipticity or compression.

In the 'Astronomische Nachrichten,' Nos. 333 and 438, Bessel has given an elaborate discussion of the figure and dimensions of the earth, founded on ten arcs of the meridian.* His final results present a remarkable accordance with those obtained by Mr. Airy. They are—

$$a=20{,}923{,}600 \text{ feet.}$$
$$b=20{,}853{,}656 \quad ,,$$
$$\epsilon=\frac{1}{299{\cdot}15} \quad ,$$

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* In 1841

Colonel Everest, in his 'Account of the Measurement of Two Sections of the Meridional Arc of India, &c.,' has deduced the elements of the earth's figure from a discussion of twelve arcs of the meridian. His final results are—

$$a = 20{,}920{,}902 \text{ feet.}$$
$$b = 20{,}853{,}642 \quad ,,$$
$$\epsilon = \frac{1}{311{\cdot}04} \quad ,,$$

In the 'Account of the Principal Triangulation, &c.,' relating to the Ordnance Survey of the British Isles, Captain Clarke has investigated the elements of the spheroid which most nearly represents the surface of Great Britain. The following are the final results obtained by him :—

$$a = 20{,}927{,}005 \text{ feet,}$$
$$b = 20{,}852{,}372 \quad ,,$$
$$\epsilon = \frac{1}{280{\cdot}4} \quad ,,$$

From these elements Captain Clarke has deduced the following results :—

1. Radius of curvature of the meridian

$$= 20{,}889{,}705 - 111{,}949 \cos 2\lambda + 250 \cos 4\lambda.$$

2. Radius of curvature perpendicular to the meridian

$$= 20{,}964{,}404 - 3745{\cdot}0 \cos 2\lambda + 50 \cos 4\lambda.$$

3. Radius of parallel

$$= 20{,}945{,}679 \cos \lambda - 18{,}700 \cos 3\lambda + 25 \cos 5\lambda.$$

4. Length of a meridian arc whose amplitude is ϕ and mean latitude λ

$$= 20{,}889{,}705\, \phi - 111{,}949 \sin \phi \cos 2\lambda + 125 \sin 2\phi \cos 4\lambda.$$

5. Length of a degree of the meridian

$$= 364{,}594{\cdot}1 - 1953{\cdot}8 \cos 2\lambda + 4{\cdot}4 \cos 4\lambda.$$

6. Length of a degree of longitude

$$= 365{,}571{\cdot}0 \cos \lambda - 326{\cdot}4 \cos 3\lambda + 0{\cdot}4 \cos 5\lambda.$$

These formulæ are, of course, applicable only to the surface of Great Britain.

In the work above cited, Captain Clarke has also investigated the elements of the earth's figure by a discussion of the totality of trustworthy arcs of the meridian hitherto measured on the earth's surface (with the exception of Mr. Maclear's arc). The following are the final results :—

$$a = 20{,}926{,}348 \text{ feet.}$$
$$b = 20{,}855{,}233 \quad ,,$$
$$\epsilon = \frac{1}{294{\cdot}26} \quad ,,$$

These elements give for the radius of curvature of the meridian the following expression :—

$$\rho = 20{,}890{,}805 - 106{,}678 \cos 2\lambda + 227 \cos 4\lambda.$$

And for the length of a meridian arc whose amplitude is ϕ and mean latitude λ, the following value :—

$$s = 20{,}890{,}805,\ \phi - 106{,}678 \cos 2\lambda \sin \phi + 113{\cdot}5 \cos 4\lambda \sin 2\phi.$$

From the same elements the value of a mean degree of the meridian is found to be

$$= 364{,}613{\cdot}33 \pm 3{\cdot}0 \text{ feet,}$$

whence the length of the ideal mètre

$$= 39{\cdot}37840 \pm {\cdot}000324 \text{ inches.}$$

Captain Clarke has subsequently shown ('Monthly Notices of the Royal Astronomical Society,' vol. xix., page 36) that the introduction of Mr. Maclear's value of the Cape arc into the investigation does not sensibly modify the final results.

The most recent investigation of the figure of the earth is due to General Schubert. ('Essai d'une Determination de la veritable Figure de la Terre, Mem. de l'Acad. Imper. de St. Petersbourg,' vii. serie, tome i., No. 6; 'Monthly Notices of the Royal Astronomical Society,' vol. xx., page 104.) His investigation is based upon eight arcs of the meridian, in which the longitudes are measured eastwardly from an imaginary meridian 20° west of Paris.

	Latitude.			Longitude.
Russian arc	45° 20′	to	70° 40′	44° 23′
Indian arc	8 10	,,	20 31	95 20
French arc	38 40	,,	51 2	20 0
Cape arc	−29 44		−34 21	36 9
Peruvian arc	0 3	,,	−3 5	298 44
Prussian arc	54 13	,,	55 43	38 10
English arc	50 37	,,	60 50	17 40
Pennsylvanian arc	38 27	,,	39 56	300 10

Combining these arcs two and two, General Schubert obtains twenty-eight different sets of elements exhibiting great discordances. He is thereby led to suspect that the earth is not a solid of revolution. If this surmise be correct, then all comparisons of arcs of meridian under different longitudes are inadmissible. Assuming the terrestrial meridians to be ellipses and the minor axis to be constant for all meridians, he proceeds to determine the value of the minor axis by a comparison of two different sections of the same arc. Treating the Russian arc and the Indian arc in this way, he obtains two different values of the minor axis agreeing nearly with each other. The mean of the two results gives 3,261,468 for the number of toises contained in the polar semi axis.

With this value of the minor axis General Schubert investigates the major axes of the meridians of the Peruvian, Russian, and Indian arcs. The following are the results obtained by him :—

	Longitude.	Toises.
Major axis of Peruvian meridian	298° 44′	3,272,383
,, Russian ,,	44 23	3,272,650
,, Indian ,,	95 20	3,272,581

Assuming the terrestrial equator to be an ellipse, General Schubert calculates its elements from the foregoing three radii vectores, and thus finds,

Major semi-axis 3,272,671 ; its longitude 58° 44′ or 238° 44′
Minor semi-axis 3,272,303 ; its longitude 148° 44′ or 328° 44′.

The combination of these with the polar meridian gives $\frac{1}{292}$, and $\frac{1}{302}$ for the values of the ellipticity of the two principal meridians.

With these elements General Schubert computes the radii of the equatorial ellipse corresponding to the different arcs. These radii are of course the major axes of the respective meridians. With the arcs computed from these elements, and the astronomical differences of latitude, the geodetic measures are compared. The residual differences are as follows :—

Arc of Meridian.	Geodetic amplitude.—Astronomical Amplitude.
Peruvian arc	+ 0″·077
Pennsylvanian	−6 ·687
English	+0 ·736
French	−1 ·607
Cape of Good Hope	−0 ·442
Prussian	+1 ·267
Russian	−1 ·289
Indian	+1 ·619

The Pennsylvanian arc was measured entirely with rods; it is not entitled to any confidence. In the Indian arc no account is taken of the disturbing influence produced by the attraction of mountains.

For the values of the terrestrial ellipticity deduced from oscillations of the pendulum in different latitudes, and from the theory of the moon's motion, see the articles PENDULUM and MOON.

GEOGRAPHY (a term derived from the Greek *γεωγραφία*, *geográphia*) is a science the general object of which is to describe the surface of our globe. Its more special object is to ascertain and describe such physical peculiarities in each country as tend to promote or retard the increase of population and the arts of civilised life.

The political condition of a nation and the changes to which it is subject are in a great degree dependent on the character of the country which it inhabits, or of those countries which surround it. The difference in civilisation observed in nations living near one another may also in a great degree be ascribed to the same cause. Accordingly we find that as soon as men began to apply themselves to the explanation of such changes and differences, they were obliged to look to the particular character of the countries inhabited by those nations whose history it was their object to investigate. Geography is coeval with history. It is as impossible to form a just idea of the events which have been most decisive in the history of a nation without a knowledge of their country, as it is to understand the movements of two armies on a field of battle without knowing the nature of the ground which is the scene of their operations.

The first traces of anything like a geographical system, in the literature of the western world, occur in the Homeric poems. According to the Rev. Mr. Bevan, the learned author of the department of Ancient Geography in the 'Manual of Geographical Science,' we should be warranted in saying, that these represent the state of geographical knowledge down to the commencement of the 9th century, B.C. "Not that there is any methodical exposition of the views of the age on this subject," says Mr. Bevan; "the nature and matter of the poems would not admit, nor lead us to expect, as much; but the incidental notices are numerous enough to enable us to picture to ourselves the world as Homer conceived of it, and have therefore obtained for him the reputation of being the first geographer. . . . . . Homer, like many of his successors, was totally ignorant of the *spherical* form of the world; he conceived it to be a flat circular body, the upper face of which was the habitation of *men*, while the lower was the region of Tartarus, the abode of the punished *gods*. Over the earth stretched the vault of heaven, and round it flowed incessantly the stream of ocean. The heaven rested in its extremities on the surface of the earth." The ocean which surrounded the earth like the rim of a shield, is always spoken of as a *river* or *stream*, differing in character from all other bodies of water, and yet the parent of them. The land of Hellas was deemed the centre of the world's circle. The continents are not distinguished as such, nor are they designated by any general names; for Asia applies only to the upper valley of the river Caïster; and Europe seems to be confined to Greece, north of Peloponnesus. Libya signifies a part of the African coast west of Egypt. We also read of the land and river of Egypt (the name of Nile does not yet occur), with the ancient Thebæ and the isle of Pharos.

In the third volume of 'Studies on Homer and the Homeric age,' by the Right Hon. W. E. Gladstone (1858), is an elaborate investigation, under the head of 'Thalassa: the outer Geography of the Odyssey,' of the terrestrial system of Homer, of which he has constructed a map accompanying the volume. He infers, however, that in Homer's estimation the form of the world was not circular, but oval, having a shorter diameter from east to west than from north to south. In the map it has the form of a parallelogram with rounded angles, equally satisfying the condition of unequal diameters, and agreeing with the oblong form of the shield in the time of Homer; our information respecting the figure attributed to the earth being derived by implication from the form of the shield of Achilles. The outer geography consists, first, of a great mass of fabulous and imaginative geographical elements; and, secondly, of certain forms of sea and land, genuine, and though wholly or partially misplaced, yet recognisable by their general likeness to their originals in nature. The Greek world of geography proper, as described above, is the inner one. The whole strongly reminds us of the Chinese map of the world.

In the age of Hesiod (800 B.C.) the knowledge of geography had considerably extended, particularly towards the west, a general improvement in the notions of European localities having taken place; the Nile also is mentioned under its proper name, and the south of (the ancient) Africa had become the recognised abode of the Æthiopians, whom Homer had placed in the east and west. The close of the 7th century witnessed the first essay at maritime discovery, in the well-known attempt of the Phœnicians to circumnavigate Libya; but the circumnavigation of Africa always remained a problem to the ancients, much in the same way that the north-west passage has been to navigators in modern times. The merit of the discovery of the *spherical* form of the earth is due to the Pythagoreans, who came to that conclusion from astronomical observations, but whether Pythagoras himself was aware of the truth is uncertain; it was not received generally in Greece until the age of Plato. The logographers, or legend-writers, now contributed most signally to the advance of practical geography by the descriptions they gave of various quarters of the globe. There were many others who wrote accounts of their own travels, among whom was Himilco, "whose narrative," says Mr. Bevan, "is to a certain extent preserved to us in the works of Avienus. He discovered the British isles, Albion, and Ierne, and mentions the Œstrymnrides, *Scilly Islands*, which he calculated a four months' voyage from the coast of Tartessus." In the works of Æschylus we find the opinions of the age in which Herodotus lived, before his geographical system had been accepted. They represent the world as a circular (?) body, with Delphi in the centre, surrounded by the ocean, which is rightly deemed a sea, and not a river. In place of the *two* sides of the world, we hear of the *four* quarters, north, south, east, and west. We further find that he adopted the division of the land into three continents; the river Phasis separating Asia, and the Straits of Hercules Libya, from Europe.

Herodotus, the father of history, is likewise the father of geography, in the sense that his writings formed the commencement of a more real and enlightened system, the materials of which, as will presently be shown, were drawn from actual observation and scientific research. His geographical descriptions are short and general, but always clear, and sufficient to show how far the physical peculiarities of each country influenced the changes and events which he had undertaken to commemorate. When he found that a country was characterised by striking peculiarities, he described them at considerable length. Instances of this are his description of Egypt in the second, and his description of the Scythians and their country in the fourth book.

From the preliminary chapters on the life and writings of Herodotus, prefixed to the new English version of his history, by Mr. Rawlinson (1858), it appears that his active and inquisitive turn of mind led him at an early age to engage in travels, the extent of which, combined with their leisurely character, clearly shows that a long term of years must have been so occupied. Herodotus visited Babylon, Ardericca near Susa, the remoter parts of Egypt, Scythia, Colchis, Thrace, Cyrene, Zante, Dodona, and Magna Græcia; thus covering with his travels a space of thirty-one degrees of longitude (above 1700 miles), from east to west, and twenty-four of latitude (1660 miles) from north to south. "Within these limits, moreover," Mr. Rawlinson observes, "his knowledge is for the most part close and accurate. He has not merely paid a hasty visit to the countries, but has examined them leisurely, and is familiar with their scenery, their cities small and large, their various wonders, their temples, and other buildings, and with the manners and customs of their inhabitants. The fulness and minuteness of his information is even more remarkable than its wide range, though it has attracted less observation. In Egypt, for instance, he has not contented himself with a single voyage up and down the Nile, like the modern tourists, but has evidently passed months, if not years, in examining the various objects of interest." In fact, to whatever extent he was indebted to earlier authorities for his preparatory culture, the real source of almost all that he has delivered to us in the shape of geographical description, was personal observation and inquiry. His accounts of countries are, in the great majority of cases, drawn from his own experience, and are full or scanty according to the time which he had spent in the countries in making acquaintance with their general character and special phenomena. Where he has not travelled himself, he trusts to the reports of others, but only, to all appearance, of eye-witnesses. If in any case he gives mere rumours which have come to him at second-hand, he is careful to distinguish them from his ordinary statements and descriptions. He seems to have been indefatigable in laying under contribution all those with whom his active and varied life brought him in contact, and deriving from them information concerning any regions unvisited by himself, with which they professed themselves acquainted." By these means, concludes the latest interpreter of, and commentator upon, Herodotus, "he gathered the materials for the geographical portion of his work."

There is, however, something vague in the descriptions of Herodotus, for want of a means of referring to the position of places as determined by astronomical observations. Herodotus, indeed, was apparently not fully acquainted with the state of science, and particularly astronomical knowledge, as it existed in his age. Thales had some time before calculated an eclipse of the sun, and from his epoch astronomy attracted the attention of the Greek philosophers, and facts in this science began to accumulate. It was, however, soon evident that most of these facts lost a great part of their value, from the circumstance of the position of places not being ascertained. Astronomers, therefore, were led to devise a method of fixing the latitude and longitude of a place; and though this method, when compared with our practice, was extremely rude and imperfect, yet it must be considered as having materially contributed to the improvement of geography. With the help of such astronomical observations as were made by his predecessors or himself, Eratosthenes formed the first system of geography founded on a basis which in some degree approached to truth. He determined the geographical position of a great number of places, many of them hardly known to Europeans; but these determinations were often founded on vague information, and consequently were in a great degree conjectural. Still his map gave a much truer image of the figure of the world than philosophers had formed before him, as he took care to subject his information to a strict examination.

While his successors were slowly improving his work, the historians, following up the plan traced by Herodotus, enriched geography with the description of those countries which at the time of the historian of Halicarnassus were not known, or at least only imperfectly known in Greece. Among these historians Polybius deserves particular mention. His geographical descriptions of the countries which inclose the western portion of the Mediterranean Sea are as good as, if not superior to, those by Herodotus of the countries between the Caspian Sea and the Gulfs of Persia and Arabia. About this time, or shortly afterwards, it would seem that several persons undertook travels into remote countries, in order to investigate their physical character, and to ascertain the accuracy of such information as had reached them by hearsay. The most conspicuous among these adventurers was Posidonius. Like Alexander von Humboldt, he went to the then remotest accessible part of the earth, to Iberia, which was as noted for its mines of the precious metals as South America and Mexico are in our times; and though only a small portion of the information which he collected has come down to us, he seems to have paid great attention to nearly all the objects of inquiry which the German philosopher has investigated.

The geographical information collected by these eminent travellers and many others of less note was scattered over a great number of works, access to which, in the circumstances of those times was necessarily difficult. Strabo, a native of Asia Minor, who wrote in the time of Augustus and Tiberius, undertook to incorporate in one work those scattered materials, and to add the information which he had acquired in his own travels. His object, according to his own declaration, was to compose a work which should be useful to those employed in the administration of countries. He accordingly discarded everything which was only of temporary importance, and described each country according to its permanent physical character. In a few words he informs his reader of the extent of each country under description, and its chief political and historical divisions. Passing on to the detailed description of these divisions, he follows much more nearly the course of our modern travellers than that of our geographers. Mountains, plains, valleys, rivers, and towns keep their true position with respect to one another; productions and climate are mentioned in their proper place. A few short observations on the commerce and the articles of export conclude his description. By this judicious arrangement the sagacious Greek geographer avoided causing to his readers that weariness which every one experiences in perusing common geographical books, in which every object is, as it were, rooted out from its natural place and transported to a foreign spot. We cannot help thinking that the method of treating geography adopted by Strabo ought still to be considered as a model, and ought to be again introduced into works of this class: the late Charles Ritter, in his justly esteemed geographical works, strictly adheres to the plan of Strabo.

Whilst the geography of Strabo was extensively used all over the Roman world, the astronomical school of Alexandria continued collecting materials for the purpose of completing and perfecting the system of mathematical geography framed by Eratosthenes. These collections enabled Ptolemy to form his Geography, which is hardly anything else but a catalogue of places according to their estimated or determined geographical position. In its time it was certainly a very useful work, but its value to us consists chiefly in showing how far the Greeks had carried their knowledge of the surface of the globe. From the time of Ptolemy up to the 14th century scarcely anything was added to what he left behind him.

The downfal of the Roman Empire, and the occupation of Western Europe by barbarous nations who were hardly acquainted with the elements of civilised life, suddenly extinguished all scientific research. Many centuries elapsed before these nations made such progress in civilisation as to enable them to turn their attention to science. Geography, which shared the fate of the other sciences, was, however, revived sooner than the rest, and the circumstance which led to this was the publication of the travels of the Venetian, Marco Polo. Though his accounts were rejected by his countrymen as mere fictions, or at any rate were treated as great exaggerations, some German scholars at Nürnberg took a different view of them. As Nürnberg at that time was one of the greatest trading places on the Continent, and for that reason closely connected with the first commercial houses of Venice, these learned men soon procured a copy of Marco Polo's travels. For the other countries of the world, taking Ptolemy as their basis, they introduced the principal geographical facts contained in Polo's travels into their globes and maps, as an addition to the knowledge transmitted by the astronomers of Alexandria. But Marco Polo had made no astronomical observations, nor had he even mentioned the length of the longest day at any place. The German geographers were therefore obliged to determine the extent of the countries which he had traversed by his vague estimates of days' journeys; but the length of these journeys was greatly exaggerated by them, as they were entirely unacquainted with the peculiar character of Eastern Asia. The consequence of this was, that on their maps and globes Asia extended over the whole of the Pacific, and its eastern shores were placed very nearly where the Antilles are situated. This error of the geographical school of Nürnberg was attended with very important consequences. Columbus, relying on their estimates, considered that the shortest way to arrive at the eastern parts of Asia would be by sailing to the west. He found America; but the same school of geographers whose errors had induced him to venture on such a voyage deprived him also partly of the honour due to his great discovery. Baron von Humboldt proved that the very slow and insecure communications which then existed between Spain and Germany brought the news of the discovery of the New World to the geographers of Germany, with the names of Columbus and Americo Vespucci together, and that the Germans thought that Americo was the true discoverer of the new continent, which accordingly obtained from them the name of America, a name that has become universal.

The details of this subject will be found in Humboldt's elaborate work entitled 'A Critical Examination of the History of the Geography of the New World, and of the progress of Nautical Astronomy in the 15th and 16th centuries.' It is an immense digest of the geographical information of the later periods of classical antiquity and of the middle ages as well as of the times to which it more expressly relates. Many important results of the investigation have also been given by the author in his 'Cosmos.'

The first half of the 16th century was entirely employed in discovering the extensive coasts of America, and the countries and islands lying along it, and in the Indian Ocean; and geographers were fully employed in inserting these new discoveries in their maps according to such determinations of positions as they could obtain. In all the geographical works written during that century this characteristic is observable. They resemble much more the geography of Ptolemy than that of Strabo. But what could geographers then know of the interior of countries whose very coasts were yet hardly laid down with accuracy even in a few places!

In the mean time the other sciences had been revived and with them also the study of antiquity, which gave a different turn to the study of geography during the 17th century. Many persons well informed in ancient history visited Greece and the countries of Western Asia, with the view of examining those parts which had once been the theatre of great events. Such *historical* travellers were very numerous during the second half of the 17th and the first half of the 18th century; and though at first they confined their researches chiefly to such places as had obtained some historical celebrity, they afterwards extended their views to the physical character of the countries in which such places were situated, and gave us some excellent descriptions of them, such as we find in the travels of Chardin, Shaw, Pococke, Chandler, and Carsten Niebuhr. These travels greatly contributed to the improvement of geography as a science. They brought history and geography again into close connection. Before this time geographical works contained hardly anything beyond a dry catalogue of names of places, rivers, and political divisions. But in describing the still existing ruins of places celebrated in ancient history geographers were compelled to go back to those ancient authors who had treated of these places, and thus a part at least of the geographical knowledge of Herodotus, Polybius, and Strabo, was transplanted into our modern geographical treatises. Thus a great deal of very interesting and useful matter found its way into treatises on geography, which had hitherto been entirely excluded, partly because it had not been known, and partly because it had been considered as foreign to the object of the science. If any person will take the trouble to examine any of the geographical works of the middle of the 17th and 18th centuries, he will find that more than three parts out of four of their contents have changed in the course of 100 years.

Still the science of geography remained in a very imperfect state. Only a few spots in each country had been described with any degree of precision. The peculiar character of an entire country, and of its component parts, had never been made a subject of inquiry. It had never been a subject of investigation, how far the physical character of a country was favourable or adverse to the civilisation of its inhabitants. This has now in a great degree been effected by the naturalists and other men of science, who during the last and the present century have visited nearly every part of the globe. In course of time the researches of travellers and voyagers have thus been extended to a greater number of new objects. At first they limited their labours to the extension of Natural History, adding a few observations on the countries through which they passed. Thus Tournefort, who travelled through Asia Minor, Armenia, and Persia, may be considered as the first travelling naturalist. But by examining the natural productions of a country, travellers were insensibly led to an investigation of their climate. In their attempts to establish the mean temperature of different places, and its effects on vegetation and animal life, they soon perceived the great influence which a variation in elevation above the level of the sea has on both. Thus they gradually learned that nearly every country is divided by nature into a smaller or greater number of parts materially differing in climate and natural productions. The knowledge of this fact mainly contributed to give geography a new character, and to introduce new and important elements into the geographical descriptions of countries, such as we find in the works of Pallas, Dr. Francis Buchanan Hamilton, and Alexander von Humboldt. What these great men, and several of their less distinguished predecessors, did, and what their eminent successors, such as Dr. Bebe, Prof. James Forbes, Dr. Thomas Thomson, Dr. Joseph D. Hooker, Mr. A. R. Wallace, and others, have continued to do, for the countries out of Europe, has been accomplished with equal success for the European continent by the labours of numerous excellent writers.

Geography, then, in its present state, and in its practical application, has for its object the determination of all those facts, as to any given country, which will enable us to judge of its fitness to provide man with food, and to promote his civilisation. As a science, its object is to deduce, from all the observed phenomena within its sphere, those general principles which enable us from certain known facts, as to any given country, to infer others not ascertained, and which indicate what are, as to each portion of the earth, the proper objects of inquiry. It is not every part of a country that possesses equal advantages for the habitation of man. Some parts are more favoured by soil and climate than others. There are also tracts which are inferior in both respects, but by the aid of other advantages, especially those of easy communication, have risen to a higher degree of prosperity and cultivation than many others in their neighbourhood which are more favoured in soil and climate. No correct knowledge of a country can be acquired unless the parts of it which are distinguished by their natural advantages or disadvantages are separated from each other, and unless a particular description is given of each, with its extent, and the proportion which it bears to the whole country. The first business of the geographer then must be to make this separation. His next business is to give a particular description of each of these natural divisions, beginning with the most essential fact, its elevation above the sea. If it is a valley, he notices its elevation at its origin and its termination, observing where its descent is regular and gradual, and where it declines with greater rapidity. If it is a plain, he notices at least its mean elevation, and observes in what cases it extends in a flat level, and in what cases it has an undulating surface; also if a smaller or larger portion of it is covered with swamps. This description of the surface is followed by that of the water-courses or drainage. After determining the sources of a stream, and the direction and length of its course, he mentions the amount of depression of its bed below the general surface of the valley or of the plain; and when it drains a plain, if there are bottoms or river-valleys formed on the surface of the plain, he mentions also the general extent of these bottoms. The distance to which a river is navigable is the next object of inquiry: if there are any natural impediments to the navigation, and if any successful attempts have been made to remove them, these facts also require mention. The extent of surface drained by each river, or by all the streams which ultimately unite in one channel; in other words, the extent of each river-basin, must also be ascertained. Next follows the climate. Here two points especially are to be attended to: the temperature of the air and the quantity of rain which falls, and of moisture in the atmosphere. As for the temperature of the air, not only the mean annual temperature is to be given or ascertained, but also that of the different seasons, and the regularity or irregularity of its changes, as such changes generally affect the health of the inhabitants in a sensible degree. As to moisture or rain, not only the annual quantity that falls should be noticed, but also its distribution at the different seasons. The character and the duration of the seasons must also be observed, and the prevalent winds; and especially the effect of the seasons on the progress of vegetation. It is necessary to know all these facts before a just notion can be formed of the fitness of any given tract of country for providing a population with food. And this capability of a country for the production of food,—or, in other words, its capabilities for agricultural purposes, is one of the most useful branches of geographical inquiry. The nature of the soil, and its fitness for different productions adapted to the climate of the tract, are therefore matters of primary importance in a geographical description. It is here proper to enumerate those objects of agriculture which are raised for food and as materials for clothing, and the proportion between the labour which they require and the value of the produce; and, in the next place, such productions as could be raised with ease and advantage, but which are not cultivated to any extent. Those objects which form articles of export, and enter into the market of the world, also claim a notice; and also such indigenous plants as are either of some use in the domestic economy of the inhabitants, or furnish a commodity for foreign trade. It is not the business of the geographer to enumerate all the particulars which constitute the botany or zoology of a district, for that would enlarge his science beyond all bounds and encroach upon the limits of others: the principle that must guide him in determining how much and what he must include in his geographical description of the botany and zoology of a country, will always be indicated by the question, Does the thing or object inquired after materially influence the capability of the country as a place fitted for the residence of man? Besides the useful domestic animals, it is only necessary to mention such wild ones as are useful to the inhabitants, either by providing them with food and clothing, or by supplying an article of commerce; and these animals only need be mentioned when they are found in great numbers. As for the mineral wealth of a country, the notice of that will be limited to those substances which are worked for the use of the inhabitants or for exportation.

In this way we conceive the geographer ought to describe in detail each natural division of a country; and when he has described two such tracts which are contiguous to one another, he must point out the boundary-lines by which nature has separated them, and the obstacles which she has placed to their mutual intercourse. If he finds that such boundary-lines are formed by mountain ranges, he has to notice their mean elevation, and likewise that of the mountain-passes by which the dividing range is crossed. He must also add what natural productions of the range contribute to the sustenance or comfort of the inhabitants of the adjacent tracts. When the range has numerous offsets and extensive valleys, and consequently occupies a considerable part of the country, he must treat it as a separate natural division, and describe it in detail like any other natural division.

When the geographer has described every natural division of a country in this way, and incorporated in his description the best attainable information on all the above-mentioned points, we think that he has done his duty, and may consider his labour as terminated. But our geographical treatises still contain other matter, which is not comprehended within the above enumeration of objects belonging to the science of geography. This extraneous matter is taken either from statistics, or from what is popularly called natural philosophy or from history; and it ought to be considered how far it is expedient to admit such matters into geographical treatises.

The knowledge of a country would properly be considered as incomplete without a general notion of the most important commercial and manufacturing towns within it. Such towns must therefore be mentioned, and at the same time it should be stated how far they facilitate the internal and external intercourse of a country. The political divisions of the country may be added or omitted; when added, they should be mentioned briefly, and in a very general way. Good maps supply any deficiency in geographical works in this respect.

We do not venture to exclude entirely from geographical works all mention of natural phenomena peculiar to a country. Some of these, as volcanoes and earthquakes, though they do not exercise a permanent influence on the welfare of the inhabitants, are frequently destructive of property or life, or of both. For that reason they ought to be noticed. Such phenomena as warm or mineral springs seem also to claim a notice, especially if distinguished by peculiar characters, as the Geysers in Iceland.

It is more difficult to determine how far it is proper to describe the remains of antiquity in geographical works. When the ruins of a great city still exhibit remarkable traces of its ancient grandeur, they certainly cannot be altogether excluded. But the true solution of these and other difficulties of the kind that may be suggested as to the matter admissible into a geographical treatise, seems to be this: these subjects are *specialties*, and if they belong to geography at all, do not belong to it as necessary component parts of it, but stand to it in such a relation as to admit of being introduced or omitted according to the taste and judgment of the writer, who in this, as in all branches of knowledge whose boundaries are incapable of precise determination, will show his good sense and his clear comprehension of his subject as much by what he omits as by what he takes in.

The political institutions of a country belong to its history, and not to its geography, and ought certainly to be excluded from geographical treatises, though they form a necessary part of most statistical and of all historical works. In the Admiralty 'Manual of Scientific Inquiry,' third edition (London, 1859), will be found the views which are suggested by the recent rapid progress of geographical science, on the principal points to which, in respect of geographical investigations, the attention of travellers should be mainly directed, embodied in an article by Mr. W. J. Hamilton, F.R.S., some time President of the Royal Geographical Society of London.

The local subjects of Descriptive Geography constitute in their alphabetical arrangement the GEOGRAPHICAL DIVISION of the ENGLISH CYCLOPÆDIA. The subjects of Physical Geography, considered as objects of science, such as DESERTS, FORESTS, MOUNTAINS, RIVERS, &c. will be found in their proper alphabetical places in the present division; and those belonging to the Geographical Distribution of organised beings have been given under their appropriate heads in the NATURAL HISTORY DIVISION. [ASTRONOMY; CHART; CLIMATE; GEODESY.]

GEOMETER, a person who is skilled in geometry; but the term had its meaning settled at the time when geometry was by very much the most important branch of mathematics: and now it generally means mathematician. For instance, the French (who make considerable use of the term) call Laplace *un géomètre*, though his writings are exclusively algebraical. The term must then be understood to signify simply mathematician.

GEOMETRICAL. Of this term, as opposed to algebraical or arithmetical, nothing need be said; but the peculiar conventions of geometry oppose it most frequently to the term *mechanical*. Every construction which can be made by the ruler and compasses, that is, which demands no points except such as can be found by the intersections of straight lines and circles, is *geometrical*: every construction which requires any other curve, or which tacitly requires such a motion of a straight line or circle as would generate any other curve, is *mechanical*. The reason is that it pleased the Greeks to use these terms as distinctive of the things which can and cannot be done by the straight line and circle only: a real and important distinction with an unfortunate name. For though names, when clearly understood, are of little consequence, yet this convention of geometry has caused many to waste their time and misapply their talents. A man, for instance, not well versed in mathematics, hearing that a *geometrical* quadrature of the circle has long been sought, and never been found, sets his invention to work, easily discovers a (mechanical) method of proceeding, and imagines that everything is geometrical which employs lines, solids, &c. in space.

The conic sections were not considered by the Greeks as geometrical instruments. Several writers speak as though the contrary had been the case; but it is certain that the solution by Menechmus of the problem of two mean proportionals, which employs the parabola, was not considered by Eutocius (who records it) as more geometrical than the others which he gives.

GEOMETRICAL PROGRESSION, PROPORTION, &c. [PROGRESSION, PROPORTION, &c.]

GEOMETRY (*γεωμετρία, geométria*, or land-measurement), the science which investigates the relations existing between parts of space, whether linear, superficial, or solid. But at the same time, the most common meaning of the word implies that the investigation is to take place under restrictions as to the instruments which may be employed. Of this we shall see more when we come to the geometry of the Greeks; in the meanwhile, geometry may be generally defined as the science of space. The closeness of the connection between *geometry*, and *Euclid* its founder, has made the two names almost identical. Although therefore, a part of the present article has been given in the BIOG. DIV. under the name of EUCLID, it is repeated here with some additions. As geometry is in all probability the most ancient subject to which actual demonstration was applied, we may thus account for the permanent association which has always existed between the idea of this science and that of rigorous deduction. To reason geometrically is a synonyme for to reason strictly: but abandoning this particular view of geometry, we shall devote the present article principally to such an imperfect sketch of the early progress of the science as its meagre history, combined with the narrowness of our limits, will allow.

There is a *stock history* of the rise of geometry, supported by the names of Strabo, Diodorus, and Proclus, namely, that the Egyptians, having their landmarks yearly destroyed by the rising of the Nile, were obliged to invent an art of land-surveying in order to preserve the memory of the bounds of property; out of which art geometry arose. This story, combined with another attributing the science directly to the gods, forms the first light which we have on the subject, and both in one are worthily sung by the poet who figures at the head of an obsolete English course of mathematics:—

"To teach weak mortals property to scan,
Down came geometry and formed a plan."

There is no proof whatever that the Egyptians were more of geometers than of astronomers [Astronomy], and the supposition that the rise of the Nile obliged the builders of the pyramids to make new landmarks once a year, requires at least contemporary evidence to make it history. At the same time, the question of the actual origin of geometry is a very difficult one, and any conclusion can only be of very moderate probability.

Among the Chinese, the Jesuit missionaries found very little knowledge of the properties of space; a few rules for mensuration, and the famous property of the right-angled triangle being all that they could ascertain. Of all the books which Gaubil could find professing to be written before B.C. 206, there is only one which contains anything immediately connected with geometry. From this writing (called Tcheou-pey) it is not very certain whether the Chinese possessed the property of the right-angled triangle generally, or only one particular case; namely, when the sides are 3, 4, and 5: and nothing appears which directly or indirectly resembles demonstration. The Hindoos produce a much larger body of knowledge, but of uncertain date. The works of Brahmegupta and Bhascara, of the 7th and 12th centuries after the Christian era (according to Colebrooke), contain a system of arithmetical mensuration which is certainly older than the compilers mentioned, and in which the property of the right-angled triangle is made to produce a considerable number of results; for instance, the method of finding the area of a triangle of which the three sides are given. By a figure drawn on the margin of some manuscripts, it appears that a demonstration of the property in question had been obtained. [Hypothenuse.] The circumference of the circle is given as bearing to the diameter the proportion of 3927 to 1250 by the latter writer; being exactly that of 3.1416 to 1. Brahmegupta takes the proportion of the square root of 10 to 1, or 3·16 to 1. The superior correctness of the later writer could not have arisen from any intermediate communication with Europe, since the true ratio was not known so near as 3·1416 till after the 12th century; and the Persians (as appears by the work of Mohammed ben Musa) had adopted this ratio from the Hindoos, before the discovery of an equally exact ratio in Europe. This subject is noticed more in detail in the article Viga Ganita in the Biog. Div.; here we merely observe that though no date can be fixed to the commencement of geometry in India, yet the certainty which we now have that algebra and the decimal arithmetic came from that quarter, the recorded visits of the earlier Greek philosophers to Hindostan (though we allow weight rather to the tendency to suppose that philosophers visited India, than to the strength of the evidence that they actually did so), together with the very striking proofs of originality which abound in the writings of that country, make it essential to consider the claim of the Hindoos, or of their predecessors, to the invention of geometry. That is, waiving the question whether they were Hindoos who invented decimal arithmetic and algebra, we advance that the people which first taught those branches of science is very likely to have been the first which taught geometry; and again, seeing that we certainly obtained the former two either from or at least through India, we think it highly probable that the earliest European geometry also came either from or through the same country.

Of the Babylonian and of the Egyptian geometry we have no remains whatever, though each nation has been often said to have invented the science. In reference to the authorities mentioned above in favour of the Egyptians, to whom we may add Diogenes Laertius, &c., we may say that no one of the writers who tells the story in question is known as a geometer except Proclus, the latest of them all; and as if to give the assertion the character of an hypothesis, this last writer also adds that the Phenicians, on account of the wants of their commerce, became the inventors of arithmetic. In the Jewish writings there is no trace of any knowledge of geometry. So that allowing the Greeks to have received the merest rudiments either from Egypt or India, or any other country, it is impossible to name any quarter from which we can with a shadow of probability imagine them to have received a deductive system, to ever so small an extent. That their geometry, or any of it, came *direct* from India, is a supposition of some difficulty: those who brought it could hardly have failed to bring with it the decimal notation of arithmetic. That Pythagoras travelled into India, is (according to Stanley) only the assertion of Apuleius and Clemens Alexandrinus, though rendered probable by several of his tenets: the better authorities carry him no farther than Egypt.

Thales (600 B.C.) and Pythagoras (540 B.C.) founded the earliest schools of geometry. The latter is said to have sacrificed a hecatomb when he discovered the property of the hypothenuse before alluded to, and this silly story is repeated whenever the early history of geometry is given. A large collection of miscellanies might easily be made from the works of writers who were not themselves acquainted with geometry; but, rejecting such authorities, we shall content ourselves with citing Pappus and Proclus, both geometers, who, living in the fourth and fifth centuries after Christ, had abundant opportunities of hearing the stories to which we allude, and of receiving or rejecting them.

According to Proclus (book ii. ch. 4, Comm. in Eucl.) Pythagoras was the first who gave geometry the form of a science, after whom came Anaxagoras, Œnopides, Hippocrates of Chios (who invented the well known quadrature of the lunules), and Theodorus of Cyrene. Plato was the next great advancer of the science, with whom were contemporary Leodamas, Archytas, and Theætetus, of Thasus, Tarentum, and Athens. After Laodamas came Neoclides, whose disciple Leo made many discoveries, added to the accuracy of the elements, and gave a method of deciding upon the possibility or impossibility of a problem. After Leo came Eudoxus, the friend of Plato, who generalised various results which came from the school of the latter. Amyclas, another friend of Plato, and the brothers Menæchmus and Dinostratus made geometry more perfect. Theudius wrote excellent elements, and generalised various theorems. Cyzicinus of Athens cultivated other parts of mathematics, but particularly geometry. Hermotimus enlarged the results of Eudoxus and Theætetus, and wrote on *loci*. Next is mentioned Philippus, and after him Euclid, 'who was not much younger than those mentioned, and who put together elements, and arranged many things of Eudoxus, and gave unanswerable demonstrations of many things which had been loosely demonstrated before him.' He lived under the first Ptolemy, by whom he was asked for an easy method of learning geometry, to which he made the celebrated answer that there was no royal road. He was younger than the time of Plato, and older than Eratosthenes and Archimedes. He was of the Platonic sect.

Such is, very nearly entire, the account which Proclus gives of the rise of geometry in Greece.

Before the time of Euclid demonstration had been introduced, about the time, perhaps by the instrumentality, of Pythagoras; pure geometry had been restricted to the right line and circle, but by whom is not at all known; the geometrical analysis, and the study of the conic sections, as also the consideration of the problems of the duplication of the cube, the finding of two mean proportionals, and the trisection of the angle, had been cultivated by the school of Plato; the quadrature of a certain circular space had been attained, and the general problem suggested and attempted by Hippocrates and others; a curve of double curvature had been imagined and used by Archytas; writings existed both on the elements, and on conic sections, loci, and detached subjects. The little that is known of the biography of Euclid of Alexandria, will be found in the Biog. Div.

Besides the Elements, Euclid wrote, or is supposed to have written, the following works:—

1. *Σύγγραμμα Ψευδαρίων*, a treatise on Fallacies, preparatory to geometrical reasoning. This book, mentioned by Proclus, does not now exist, and there is no Greek work of which we so much regret the loss. Had it survived, mathematical students would not have been thrown directly upon the Elements, without any previous exercise in reasoning. [Mathematics.]

2. Four books of Conic Sections, afterwards amplified and appropriated by Apollonius, who added four others. So says Pappus. That Euclid did not write *any* books on conic sections—that he wrote these of Apollonius is wholly incredible—appears to us more than probable from the silence of Proclus the Platonist, who, eulogising Euclid the Platonist, and stating that he wrote on the regular solids (a part of geometry cultivated by the Platonists), being led thereto by Platonism, never mentions his writing on the still more Platonic subject of the conic sections. But that Aristæus had written on the subject is known, and that Euclid taught it cannot be doubted, any more than that Apollonius, like other writers, prefixed to his own discoveries all that he judged fit out of what was previously known on the subject.

3. *Περὶ Διαιρέσεων*, on Divisions. This work is mentioned by Proclus in two words. John Dee imagined the book of Mohammed of Bagdad (which is annexed to the English edition of Euclid hereinafter cited) on the divisions of surfaces to be that of Euclid now under consideration; but there seems to be no ground for this notion. The Latin of this work (from the Arabic) is given at the end of Gregory's Euclid, together with a fragment 'De Levi et Ponderoso,' attributed, without any foundation, to Euclid.

4. *Περὶ πορισμάτων*, on Porisms, in three books. This is mentioned both by Pappus and Proclus, the former of whom gives the enunciations of various propositions in it, but the text is so corrupt that they can hardly be understood. On this singular question, see the article Porism.

5. *Τόπων πρὸς ἐπιφάνειαν*, Locorum ad Superficiem: which we cannot translate. It is mentioned by Pappus, but has not come down to us.

The preceding works are either lost or doubtful; those which follow all exist, and are contained in Gregory's edition, in the order inverse to that in which they are here mentioned.

6. *Ὀπτικὰ καὶ κατοπτρικά*, on Optics and Catoptrics. These books are attributed to Euclid by Proclus, and by Marinus in the preface to the Data; or rather books on these subjects. Savile, Gregory, and others doubt that the books which have come down to us are those of Euclid, and Gregory gives his reasons in the preface, which are—that Pappus, though he demonstrates propositions in optics and also in astronomy, and mentions the Phænomena of Euclid with reference to the latter, does not mention the Optics with reference to the former—and that there are many errors in the works in question, such as it is not likely Euclid would have made. Proceeding on the supposition that rays of light are carried *from the eye to the object*, the first of these books demonstrates some relations of apparent magnitude, and shows

how to measure an unknown height by the well-known law of reflected light. In the second an imperfect theory of convex and concave mirrors is given.

7. *Φαινόμενα*, on Astronomical Appearances, mentioned by Pappus, and Philoponus (cited by Gregory). It contains a geometrical doctrine of the sphere, and though probably much corrupted by time, is undoubtedly Euclid's.

8. *Κατατομὴ κανόνος* and *εἰσαγωγὴ ἁρμονικὴ*, the Division of the Scale and Introduction to Harmony. Proclus mentions that Euclid wrote on harmony, but the first of these treatises is a distinct geometrical refutation of the principles laid down in the second, which renders it unlikely that Euclid should have written both. The second treatise is Aristoxenian, while the first proceeds on principles of which Gregory states he never found a vestige in any other writer who was reputed anterior to Ptolemy (to whom he attributes it). The second treatise is not geometrical, but is purely a description of the system mentioned, and as this treatise is not alluded to by Ptolemy nor by any previous writer on the subject, it is very probable that Euclid did not write it.

9. *Δεδομένα*, a book of Data. This is the most valuable specimen which we have left of the rudiments of the geometrical analysis of the Greeks. Before a result can be found, it should be known whether the given hypotheses are sufficient to determine it. The application of algebra settles both points; that is, ascertains whether one or more definite results can be determined, and determines them. But in geometry it is possible to propose a question which is really indeterminate, and in a determinate form, while at the same time the methods of geometry which give one answer may not give the means of ascertaining whether the answer thus obtained is the only one. Thus the two following questions seem equally to require one specific answer, to one not versed in geometry:—

Given, the area of a parallelogram, and the ratio of its sides; required, the lengths of those sides: and

Given, the area of a parallelogram, the ratio of its sides and one of its angles; required, the lengths of the sides.

The first question admits of an infinite number of answers, and the second of only one; or in the language of Euclid, if the area, ratio of sides, and an angle of a parallelogram be given, the sides themselves are given. The same process by which it may be shown that they are given serves to find them; so that the Data of Euclid may be looked upon as a collection of geometrical problems, in which the attention of the reader is directed more to the question of the sufficiency of the hypothesis to produce one result, and one only, than to the method of obtaining the result.

A preface to this book was written by one Marinus, the disciple and successor of Proclus, explaining at tedious length the distinction of "given" and "not given."

10. *Στοιχεῖα*, the Elements (of Geometry). For a long time writers hardly considered it necessary to state whose elements they referred to, since a certain book of the elements always signified that book of Euclid: and it was customary in England to call each book *an* element; thus in Billingsley's old translation the sixth book is called *the sixth element.*

The reason why the Elements have maintained their ground is not their extreme precision in the statement of what they demand [Axiom]; for it frequently happens that a result is appealed to as self-evident, which is not to be found in the expressed axioms. Neither does their fame arise from their never assuming what might be proved; for in the very definitions we find it asserted that the diameter of a circle bisects the figure, which might be readily proved from the axioms. Neither is it the complete freedom from redundancy, nor the perfection of the arrangement; for book i. prop. 6, which is very much out of place, considering that it is never wanted in the first book, is, in point of fact, proved again (though not expressed) in prop. 19. Neither is it the manner in which our ideas of magnitude are rendered complete, as well as definite: for instance, book iii. prop. 20, is incomplete with Euclid's definition and use of the term angle; nor with that term as used by him can the 21st proposition of that book be fully demonstrated without the help of the subsequent 22nd. In fact, the Elements abound in defects, which, if we may so speak, are clearly seen by the light of their excellencies: the high standard of accuracy which they inculcate in general, the positive and explicit statement which they make upon all real and important assumptions, the natural character of the arrangement, the complete and perfect absence of false conclusion or fallacious reasoning, and the judicious choice of the demonstrations, considered with reference to the wants of the beginner, are the causes of the universal celebrity which this book has enjoyed. We shall, in the article Mathematics, give our reasons for advocating the continuance of Euclid as a book of instruction, and shall now describe the contents of the Elements.

There are thirteen books certainly written by Euclid, and two more (the fourteenth and fifteenth) which are supposed to have been added by Hypsicles of Alexandria, of whom we do not doubt that he lived in the sixth century, though he is commonly placed in the second.

Book i. lays down the definitions and postulates required in the establishment of plane geometry, a few definitions being prefixed also to ii., iii., iv., and vi. It then treats of such properties of straight lines and triangles as do not require any particular consideration of the properties of the circle nor of proportion. It contains the celebrated proposition of Pythagoras.

From this book it appears that Euclid lays down, as all the instrumental aid permitted in geometry, the description of a right line of indefinite length, the indefinite continuation of such a right line, and the description of a circle with a given centre, the circumference of which is to pass through a given point. It is usual to say, then, that the ruler and compasses are the instruments of Euclid's geometry, which is not altogether correct, unless it be remembered that with neither ruler nor compasses is a straight line allowed to be transferred, of a given length, from one part of space to another. It is a plain ruler, whose ends are not allowed to be touched, and compasses which close the moment they are taken off the paper, of which the Greek geometry permits the use. It is altogether uncertain by whom these restrictive postulates were introduced, but it must have been before the time of Plato, who was contemporary with (if he did not come after) the introduction of those problems whose difficulty depends upon the restrictions. We may here observe that in actual construction the ruler might have been dispensed with. It was reserved for an Italian abbé, at the end of the 18th century, when all who studied geometry had, for two thousand years, admired the smallness of the bases on which its conclusions are built, to inquire whether, small as they were, less would not have been sufficient. In Mascheroni's 'Geometria del Compassa,' published at Pavia in 1797, it is shown that all the fundamental constructions of geometry can be made without the necessity of determining any point by the intersections of straight lines; that is, by using only those of circles. This singular and very original work was translated into French, and published at Paris in 1798 and 1828. It may be added that Benedetti, in the 16th century, and others after him, had shown that, granting the straight line, *only one circle* is absolutely necessary: that is, only one opening of the compasses.

On subjects particularly connected with the first book, see Axiom, Postulate, Parallels, Hypothenuse.

Book ii. treats of the squares and rectangles described upon the parts into which a line is divided. It opens the way for the application of geometry to arithmetic, and ends by showing how to make a square equal to any rectilinear figure. It also points out what modification the proposition of Pythagoras undergoes in the case of a triangle not right-angled. [Rectangle.]

Book iii. treats of the circle, establishing such properties as can be deduced by means of the preceding books.

Book iv. treats of such regular figures as can readily be described by means of the circle only, including the pentagon, hexagon, and quindecagon. It is of no use in what immediately follows.

Book v. treats of proportion generally, that is, with regard to magnitude in general. Whether this most admirable theory, which though abstruse is indispensable, was the work of Euclid himself, or a predecessor, cannot now be known. The introduction of any definitely numerical definition of proportion is rendered inaccurate by the necessity of reasoning on quantities between which no exact numerical ratio exists; for which see Incommensurables. The method of Euclid avoids the error altogether, by laying down a definition which applies equally to commensurables and incommensurables, so that it is not even necessary to mention this distinction. In the article Proportion we shall endeavour to show that this method is more simple than is generally supposed, and also that all substitutes for it have failed in rigorous deduction.

Book vi. applies the theory of proportion to geometry, and treats of similar figures, that is, of figures which differ only in size, and not in form.

Book vii. lays down arithmetical definitions; shows how to find the greatest common measure and least common multiple of any two numbers; proves that numbers which are the least in any ratio are prime to one another, &c.

Book viii. treats of continued and mean proportionals, showing when it is possible to insert two integer mean proportionals between two integers.

Book ix. treats of square and cube numbers, as also of *plane* and *solid* numbers (meaning numbers of two and three factors). It also continues the consideration of continued proportionals, and of prime numbers, shows that there is an infinite number of prime numbers, and demonstrates the method of finding what are called *perfect* numbers.

Book x. contains 117 propositions, and is entirely filled with the investigation and classification of certain incommensurable quantities. It shows how far geometry can proceed in this branch of the subject without algebra; and though of all the other books it may be said that they remain at this time as much adapted for instruction as when they were written, yet of this particular book it must be asserted that it should never be read except by a student versed in algebra, and then not as a part of mathematics, but of the history of mathematics. In the article Irrational Quantities we shall translate the phrases of Euclid into algebraical language, by means of which we have no doubt that many students will be enabled to read the book of Euclid with profit. The book finishes with a demonstration that the side and diagonal of a square are incommensurable. From this book it is most evident that the arithmetical character of geometrical magnitude had been very extensively considered; and it seems to us sufficiently clear that an arithmetic of a character approximating closely to algebra must have been the guide, as well as that some definite object was sought—perhaps the attainment of the quadrature of the circle.

Book xi. lays down the definitions of solid geometry, or of geometry which considers lines in different planes and solid figures. It then proceeds to treat of the intersections of planes, and of the properties of parallelopipeds, or what might be called solid rectangles or right solids.

Book xii. treats of prisms, cylinders, pyramids, and cones, establishing the properties which are analogous to those of triangles, &c., in the first and sixth books. It also shows that circles are to one another as the squares on their diameters, and spheres as the cubes on their diameters, in which, for the first time in Euclid, the celebrated method of EXHAUSTIONS is employed, which, with the theory of proportion, forms the most remarkable part of this most remarkable work. In the article just cited we have referred to the present one for some account of this method, which we now give.

The only method of reasoning upon the length, area, or solidity, of curve lines or surfaces, is by observing the properties of inscribed polygons or polyhedrons, which may, by sufficiently increasing the number of their sides or faces, be made to approach as near as we please to continuous curvilinearity. But since the rigour of geometry is not content with proving that a proposition may be considered as nearly true as we please, and will not infer that one line is equal to another because it can be shown that their difference is (no matter how) small; Euclid (or some of his predecessors, but most probably Euclid, if we may judge by the character of his discoveries given by Proclus) invented this method of exhaustions, which may be considered as contained in the following two propositions.

I. If from A more than its half be taken, and from the remainder more than its half, and so on, the remainder will at last become less than B, where B is any magnitude named at the outset (and of the same kind as A), however small. This proposition may be easily proved, and is equally true if the fixed proportion abstracted each time be half or less than half.

II. Let there be two magnitudes, P and Q, both of the same kind; and let a succession of other magnitudes, called X_1, X_2, X_3 . . . be each nearer and nearer to P, so that any one, X_n, shall differ from P less than half as much as its predecessor differed. Let Y_1, Y_2, Y_3 . . . be a succession of quantities similarly related to Q; and let the ratios of X_1 to Y_1, of X_2 to Y_2, and so on, be all the same with each other, and the same with that of A to B. Then it must be that P is to Q as A to B. (It is obvious, from the conditions, that if X_1 be greater than P, Y_1 is greater than Q, &c., &c.) Suppose X_1, X_2, &c., less than P, and therefore Y_1, Y_2, &c., less than Q. Then, if A be not to B as P to Q, A is to B as P to some other quantity S greater or less than Q: say less than Q. Then (by hypothesis and I.), we can find some one of the series Y_1, Y_2 . . . (say Y_n) which is nearer to Q than S is to Q; and which is therefore greater than S. Then, since X_n is to Y_n as A to B, or as P to S, we have X_n is to Y_n as P to S, or X_n to P as Y_n to S: from which, since X_n is less than P, Y_n is less than S. But Y_n is also greater than S, which is absurd; therefore A is not to B as P to less than Q. Neither is A to B as P to more than Q (which call S), for in that case S is to P as B to A: let S be to P as Q to T, then S is to Q as P to T; from which, S being greater than Q, P is greater than T. But B is to A as S to P, that is, as Q to less than P, which is proved to be impossible by the reasoning of the last case. Consequently, A is not to B as P to more than Q, or to less than Q; that is, A is to B as P to Q. Which was to be shown. Let P and Q be two circles, A and B the squares on their diameters, X_1 and Y_1 inscribed squares, X_2 and Y_2 inscribed regular octagons, X_3 and Y_3 inscribed regular figures of sixteen sides, &c.: the preceding process gives the proof that circles are to one another as the squares on their diameters.

Book xiii., the last of those written by Euclid, applies some results of the tenth book to the sides of regular figures, and shows how to describe the five regular bodies. [SOLIDS, REGULAR.]

Books xiv. and xv., attributed to Hypsicles of Alexandria, treat entirely of the relative proportions of the five regular solids, and of their inscription in one another.

The writings of Euclid continued to be the geometrical standard as long as the Greek language was cultivated. The Romans never made any progress in mathematical learning. Boethius [BOETHIUS, in BIOG. DIV.] translated, it is said, the first book of Euclid (Cassiodorus, cited by Heilbronner); but all which has come down to us on the subject from this writer (who lived at the beginning of the 6th century) is contained in two books, the first of which has the enunciations and figures of the principal propositions of the first four books of the Elements, and the second of which is arithmetical. Some of the manuscripts of this writer contain an appendix which professes to give an account of a letter of Julius Cæsar, in which he expresses his intention of cultivating geometry throughout the Roman dominions. But no such result ever arrived so long as the Western Empire lasted; and this short account of Roman geometry is a larger proportion of the present article than the importance of the subject warrants. These books of Boethius continued to be the standard text-books until Euclid was brought in again from the Arabs.

Among the last-mentioned race geometry made no actual progress, though many of the works of the Greek writers were translated, and Euclid among the rest. There are several Arabic versions, the most perfect of which is that of Othman of Damascus, who augmented the usual imperfect translations by means of a Greek manuscript which he saw at Rome. D'Herbelot (at the words Aklides and Oclides) states that the Orientals believe Euclid to have been a native of Tyre, and also that they frequently gave his name to the science which he taught. The same author gives the name of the Arabic versions, one of which, that of Nasir-eddin, the most celebrated of all, was printed at the Medicean press at Rome in 1594. The astronomer Thabet ben Korrah [ASTRONOMY] was one of the translators, or rather, perhaps, revised the translation of Honein ben Ishak, who died A.D. 873. There is a manuscript in the Bodleian Library, purporting to be the translation of the latter edited by the former.

The first translation of Euclid into Latin, of which the date can be tolerably well fixed, is that of Athelard, or Adelard, a monk of Bath, who lived under Henry I. (about A.D. 1150). We have given [CAMPANUS, in BIOG. DIV.] a summary of authorities to show that Campanus, supposed to be another translator of Euclid, lived after this period; but we are inclined to believe that this translation (so called) of Campanus (printed A.D. 1482), is in fact that of Athelard, with a Commentary by Campanus. For Campanus is not expressly described in the book as a translator (see article cited), but as a commentator; add to which, that there is in the Bodleian Library a manuscript entitled 'Euclidis, &c.. ex versione Adelardi de Arabico, una cum commento Magistri Campani Novariensis.' Scheibel (cited by Camerer and Hauber, in the preface of their edition, presently noticed) states that in his copy of Campanus the fact of the translation being that of Adelard was noted in a handwriting apparently as old as the edition itself. The point might be settled by a comparison of the printed Campanus and the manuscript in the Bodleian. With regard to this version, it is stated (in the preface just cited) that it differs from the one of Nasir-eddin. With the precedent just cited, we may be allowed to state that in a copy of Campanus which we have examined, some ancient handwriting, completely obliterated, is attached to Ratdolt's preface. Chemical means have succeeded in recovering a few unconnected words only, among which are "ben Honein" and "Tebit ben Corra," expressing perhaps the opinion of the writer that the version chosen by Adelard or Campanus was that of the two Eastern editors who have been previously mentioned.

There is a considerable number of Greek manuscripts of the Elements, for which see Fabricius, Heilbronner, and the preface of Peyrard. There is no account of the manuscripts which they consulted by the earlier Latin translators (from the Greek), nor by Gregory. It appears however that several, if not many, of the manuscripts are entitled *Εὐκλειδου στοιχειων βιβλια ιε ἐκ των θεωνος συνουσιων*, from which it was inferred that the compilation of the elements was the work of Theon, from the materials left by Euclid. It is certain that Theon, in his commentary on the Almagest, speaks of his edition (*ἐκδοσις*) of Euclid, and mentions that the part of the last proposition which relates to the sectors was added by himself. On looking at that proposition, it is found that the demonstration relative to the sectors comes after the "*ὅπερ ἔδει δεῖξαι*," with which Euclid usually ends his propositions. And Alexander, the commentator on Aristotle, who lived before Theon, calls that the *fourth* proposition of the tenth book which is the *fifth* in all the manuscripts. We can then distinctly trace the hand of Theon as a commentator, and may suspect that he performed the duty of a revising editor to the work of Euclid as it now appears; but there is not the smallest reason to suppose that Theon actually digested the work into the form which it now has. These remarks relative to the claims of Theon were first made by Sir Henry Savile, who opened the chair of geometry which he founded at Oxford by thirteen lectures on the fundamental parts of the first book of Eucid, which were delivered in 1620, and published in 1621.

We now give a short summary of the early editions of Euclid, which have appeared in Greek or Latin. It is unnecessary to specify the common editions of Simson, Playfair, &c., &c., which confine themselves to the first six books, and the eleventh and twelfth, and are generally known.

I. Editions of the whole of Euclid's works. An imperfect Latin edition, by Bartholomew Zamberti, Venice, 1505. But the principal edition of all the works of Euclid is that published by the Oxford press in 1703, under the care of David Gregory, then Savilian professor.

II. Greek editions of the Elements only. (1.) An edition curâ Simonis Grynæi, Basel, 1533, with the commentary of Proclus. (2.) The Paris edition by Peyrard, 1814–18, in three volumes quarto, containing the Elements and Data, Greek and French. It is the first edition which has readings from various manuscripts. (3.) The Berlin edition, by August, 1826, 8vo., containing the thirteen books of the Elements, in Greek, with a selection of readings from Peyrard and from other manuscripts.

III. Latin editions of the Elements only. (1.) That of Campanus, the first Euclid printed, Ratdolt, Venice, 1482. (2.) A reprint of the preceding, marked 'Vincentiæ, anno salutis, 1491.' (3.) An edition containing the text and comment of Campanus, from the Arabic; also the text and comment of Zamberti, from the Greek; Paris, Henry Stephens, 1505; and again in 1516. This edition is very commodious for a general comparison of the Greek and Arabic. (4.) Edition of Lucas Pacioli, Venice, 1509. (5.) Edition of Henry Stephens, Paris, 1516. These five editions are in folio; the second and fourth are very scarce. The first edition of Clavius is that of Rome, 1574; of Commandine, Pesaro, 1572. [Clavius; Commandine, in Biog. Div.]

IV. Earliest editions of the Elements in modern tongues. *English*:—'The Elements of Geometry of the most ancient philosopher Euclid of Megara, &c.,' by H. Billingsley, with a preface by John Dee, London, 1570, and again in 1661. *French*:—'Les quinze livres des Eléments, &c., &c.,' Par D. Henrion, Mathematicum, first edition, Paris, 1565? second, 1623, with various others. According to Fabricius, there was an edition by Peter Forcadel, in 1565. *German*:—'Die sechs ersten bucher, &c.,' by William Holtzmann, Augsburg, 1562. Scheubelius had previously given the 7th, 8th, and 9th books, in 1555. *Italian*:—'Euclide Megarense Philosopho, &c.,' per Nicolo Tartalea, Venice, 1543. *Dutch*:—'De ses erste boecken Euclidis, &c.,' dor Jan Pieterszoon Dou, Amsterdam, 1608 (or 1606). *Swedish*:—'De sex forsta, &c.,' by Marten Stromer, Upsal, 1753. *Spanish*:—By Joseph Saragoza, Valentia, 1673. Murhard (compared with Fabricius) is the authority for all of these, except the first.

It has long ceased to be usual to read more of Euclid than the first six books and the eleventh. Those who wish to see more of the Elements will probably most easily obtain those of Williamson (London, 1788, two volumes 4to.), the translation of which is very literal. Those who prefer the Latin may find all the twelve books in the edition of Horsley (from Commandine and Gregory), Oxford, 1802. The number of editors of Euclid is extremely great, but our limits will not allow of further recapitulation.

The progress of geometry is connected with the names of Archimedes, Apollonius, Theon, &c., and it continued to flourish at Alexandria till the taking of that town by the Saracens, A.D. 640. But its latter day produced only commentators upon the writers of the former, or, at most, original writers of no great note. In the articles Locus, Porism, Duplication, Proportional, will be found some of the details of the Greek geometrical analysis. Spherical trigonometry, or rather that portion of their geometry which supplied its place in astronomy, is connected with the names of Hipparchus, Meuelaus, Theodosius, Ptolemy. The following list contains the names of the most celebrated geometers who lived before the decline of the Greek language: the dates represent nearly the middle of their lives, but are in many instances uncertain:—

Thales, B.C. 600; Ameristus? Pythagoras, 550; Anaxagoras; Œnopides; Hippocrates, 450; Theodorus; Archytas? preceptor of Plato; Leodamas; Theætetus; Aristæus, 350; Perseus? Plato, 310; Menæchmus, Dinostratus, Eudoxus, contemporaries of Plato: Neoclides; Leon; Amyclas; Theudius; Cyzicinus; Hermotimus; Philippus: Euclid, 285; Archimedes, 240; Apollonius, 240; Eratosthenes, 240; Nicomedes, 150; Hipparchus, 150; Hypsicles, 130? Geminus, 100; Theodosius, 100; Menelaus, A.D. 80; Ptolemy, 125; Pappus, 390; Serenus, 390; Diocles? Proclus, 440; Marinus? Isidorus? Eutocius, 540.

The age of Diophantus is not sufficiently well known even for so rough a summary as the preceding; he is usually given to the 2nd century, we place him at the end of the 6th century.

The following is the summary of books of geometrical analysis (qui ad resolutum locum pertinent), given by Pappus as extant in his time; of Euclid, the Data, three books of porisms, and two books *locorum ad superficiem*; of Apollonius, two books *de proportionis sectione*, two *de spatii sectione*, two *de tactionibus*, two *de inclinationibus*, two *planorum locorum*, and eight on conic sections; of Aristæus, five books *locorum solidorum*; of Erastosthenes, two books on finding mean proportionals. But besides these he describes a book (of Apollonius) which treats *de determinatâ sectione*.

The manifold beauties of the Elements of Euclid secured their universal reception, and it was not long before geometers began to extend their results. It became frequent to attempt the restitution of a lost book by the description given of it by Pappus or others; and from Vieta to Robert Simson, a long list of names might be collected of those who have endeavoured to repair the losses of time. On the advance of geometry in general, the reader may consult the lives of Vieta, Metius, Magini, Pitiscus, Snell, Napier, Guldinus, Cavalieri, Roberval, Fermat, Pascal, Descartes, Kepler, &c., &c., in the Biog. Div. and also the article Quadrature of the Circle.

The application of algebra to geometry, of which some instances had been given by Bombelli, and many more by Vieta, grew into a science in the hands of Descartes (1596–1650). It drew the attention of mathematicians completely away from the methods of the ancient geometry, and considering the latter as a method of discovery, the change was very much for the better. But the close and grasping character of the ancient reasoning did not accompany that of the new method: algebra was rather a half-understood art than a science, and all who valued strictness of demonstration adhered as close as possible to the ancient geometry. This was particularly the case in our own country, and unfortunately the usual attendants of rigour were mistaken for rigour itself, and *vice versâ*. The algebraical symbols and methods were by many reputed inaccurate, while the same processes, conducted on the same principles, in a geometrical form, were preferred and even advanced as more correct. Newton, an admirer of the Greek geometry, clothed his Principia in a dress which was meant to make it look (so far as mathematical methods were concerned) like the child of Archimedes, and not of Vieta or Descartes; but the end was not attained in reality, for though the reasoning is really unexceptionable, yet the method of exhaustions must be applied to most of the lemmas of the first section, before the Greek geometer would own them.

The methods of algebra, so far as expressions of the first and second degrees are concerned, apply with great facility to many large classes of questions connected with straight lines, circles, and other sections of the cone. Practical facility was gained by them, frequently at the expense of reasoning: the time came when a new Descartes showed how to return to geometrical construction with means superior to those of algebra, in many matters connected with practice. This was Monge, the inventor of *descriptive geometry*. The science of perspective and many other applications of geometry to the arts had previously required isolated methods of obtaining lines, angles, or areas, described under laws not readily admitting of the application of algebra, and its consequence, the construction of tables. The descriptive geometry is a systematised form of the method by which a ground-plan and an elevation are made to give the form and dimensions of a building. The projections of a point upon two planes at right angles to one another being given, the position of the point itself is given. From this it is possible, knowing the projections of any solid figure upon two such planes, to lay down on either of those planes a figure similar and equal to any plane section of the solid. In the case where the section is a curve it is constructed by laying down a large number of consecutive contiguous points. The methods by which such an object is to be attained were generalised and simplified by Monge, whose 'Géométrie Descriptive' (the second edition of which was published in 1820) is one of the most elegant and lucid elementary works in existence.

The methods of descriptive geometry recalled the attention of geometers to the properties of projections in general, of which such only had been particularly noticed as could be applied in the arts of design or in the investigation of primary properties of the conic sections. From the time of Monge to the present this subject has been cultivated with a vigour which has produced most remarkable results, and promises more. Pure geometry has made no advance since the time of the Greeks which gives greater help to its means of invention than that which the labours of what we must call the school of Monge have effected. One of the most distinguished pupils of this great master, M. Chasles, published an 'Apercu historique des méthodes en Géométrie,' forming the eleventh volume of the 'Mémoires Couronnés' of the Academy of Brussels, a work of great importance in the historical point of view.

On the history of geometry, as distinguished from other parts of mathematics, there is very little to cite. The references in the article Mathematics may be consulted.

GEOMETRY OF THE GREEKS. [Geometry.]

GEOPO'NIKA (or, a 'Treatise on Agriculture'), is the title of a compilation, in Greek, of precepts on rural economy, extracted from ancient writers. The compiler, in his proemium, shows that he was living at Constantinople, and dedicated his work to the Emperor Constantine, "a successor of Constantine, the first Christian emperor," stating that he wrote it in compliance with his desire, and praising him for his zeal for science and philosophy, and for his philanthropy. This emperor is supposed by some to have been Constantine Porphyrogenitus, and the compilation is generally ascribed to Cassianus Bassus, a native of Bithynia, who however is stated by others to have lived some centuries before the time of Porphyrogenitus. The question of the authorship of the 'Geoponika' has excited much discussion. Needham, in his Greek and Latin edition of the 'Geoponika,' Cambridge, 1704, has treated the subject at great length. The work is divided into twenty books, which are subdivided into short chapters, explaining the various processes of cultivation adapted to various soils and crops, and the rural labours suited to the different seasons of the year; with directions for the sowing of the various kinds of corn and pulse; for the training of the vine, and the art of wine-making, upon which the author is very diffuse. He also treats of olive plantations and oil-making, of orchards and fruit-trees, of evergreens, of kitchen-gardens, of the insects and reptiles that are injurious to plants, of the economy of the poultry-yard, of the horse, the ass, and the camel; of horned cattle, sheep, goats, pigs, &c., and the care they require; of the method of salting meat; and, lastly, of the various kinds of fishes. Every chapter is inscribed with the name of the author from whom it is taken, and the compiler gives at the beginning of the first book a list of his principal authorities, who are Africanus, Anatolius, Apuleius, Berytius, Damogeron, Democritus, Didymus, Dionysius Uticensis (the translator of Mago, the Carthaginian writer on agriculture), Diophanes, Florentinus, Leontius, Pamphilus, Paxamus, the Quintilii, Sotion, Varro, Vindanonius, and Zoroaster. Other authors besides these are quoted in the course of the work. Two or three chapters are inscribed with the name of Cassianus, who speaks of himself in them as a native of

Maratonymus in Bithynia, where he had an estate. ('Geoponika,' book v., ch. 6 and 36.) The work is curious, as giving a course of ancient agriculture collected from the best authorities then existing. The best edition of the 'Geoponika' is that of N. Niclas, in Greek and Latin, with notes and indexes, 4 vols. 8vo, Leipzig, 1781.

GEORGIUM SIDUS. [URANUS.]

GERMAN SILVER. As its name implies, this alloy was originally produced in Germany, and was obtained by smelting an ore found at Hilburghausen, near Suhl, in Henneberg. An alloy, however, very similar in appearance and properties has long been known to the Chinese under the name of *pakfong*, or white metal.

German silver is composed of the metals nickel, copper, and zinc, though in somewhat variable proportions. The following are examples of the amounts of the several metals contained in four specimens, each of different quality :—

	I.	II.	III.	IV.
Copper . . .	59·2	60	55·0	45·7
Nickel . . .	14·8	20	20·6	34·3
Zinc . . .	26·0	20	24·4	20·0
	100·0	100	100·0	100·0

No. 1 is perhaps the commonest made. No. 2 is much used. No. 3 is a very beautiful alloy, but little inferior in beauty to silver itself; it is sometimes called *electrum*. No. 4 is the richest in nickel that can be conveniently worked. For articles requiring much soldering, about 3 per cent. of lead is introduced; and where brittleness is not an objection, 2½ per cent. of iron may be added; the hardness and susceptibility of high polish being in the latter case greatly heightened. *Tutenag*, a kind of German silver used in casting operations, is composed of 45·7 of copper, 17·4 of nickel, and 36·9 of zinc.

In furnace operations with German silver a quantity of zinc is always volatilised and oxidised, and must be allowed for by at first adding a larger quantity of that metal than is required to form the alloy.

GESTURE. [ORATORY.]

GETÆ, the name of a northern tribe mentioned in Roman history, inhabiting the country on both banks of the Danube, near its estuary, and along the western shores of the Euxine. [DACIA, in GEOG. DIV.]

GHEE, a species of butter used by the natives of India, and prepared by boiling, so that it will keep for a considerable time; it is sometimes used when a year old. The milk, when first taken from the animal, is boiled in earthen pots for at least an hour, and frequently for two and even three hours; it is then allowed to cool, and a little curdled milk, called Dhye, is added to promote its coagulation. By the next morning the whole mass has been converted into dhye, or coagulated acid milk. About five or six inches in depth are then taken from the top of each pot and put into an earthen jar, where it is churned by turning round in it a split bamboo with a very quick motion. After half an hour's churning, some hot water is added, and the operation is continued for another half-hour, when the butter forms. When this butter has been kept two or three days, and has become rancid, as it will during that time in so hot a climate, it is melted in an earthen pot, and boiled until all the water that may be mixed with it is evaporated; a little dhye and salt, or betel-leaf, is then added, and it is put into pots to be kept for use. It has a strong smell, and, although very distasteful to Europeans, is in general consumption among all the natives who can afford to buy it. Ghee is a very important article of internal traffic through a great part of India.

GHIBELLINES. [GUELPHS.]

GIBBOUS, convex on both sides; a term particularly applied to the moon when more than half grown.

GIFT (Law), *donum*, *donatio*, is the transferring of the property in a thing by one man to another, voluntarily and without any valuable consideration.

The giver is called the donor, and he to whom the thing is given is called the donee. By the common law, real estate might pass as a gift by livery of seisin without deed; but by stat. 29 Charles II. c. 3, a deed or note in writing is rendered necessary to the transfer of real estate. To complete a gift of goods and chattels, not effected by writing, delivery is absolutely necessary; for until then the transaction is not properly a gift, but a contract, and the English law will not compel a man to perform his contract unless it is founded on good or valuable consideration.

Gifts are looked at with some degree of suspicion by the law of England, and are in some cases declared void, as against creditors and purchasers for a valuable consideration. [BANKRUPT.]

The distinctions laid down by the civil law as to gifts were numerous. It distinguished gifts into two classes, proper and improper: the proper gift being such as is recognised by the English law; the improper, gifts in consideration of marriage, and that species of gift termed *donatio mortis causâ*. According to the law of England, marriage is a valuable consideration, and consequently gifts upon that account are supported against purchasers and creditors.

Many curious distinctions relating to gifts exist in the Hindoo law. (See Colebrooke's 'Digest, Hindoo Law,' b. ii., c. 4.) As to the law regulating voluntary gifts established by the Code Napoleon, see 'Cod. Civ.,' b. 3, tit. 2.

GILDING. Although there are many varieties of gilding, the only kinds which need separate mention in this place are *Metal-gilding* and *Wood-gilding*. The reader will find an account of the modern process of *Electro-gilding*, under ELECTRO-METALLURGY; of *Fibre-gilding*, under GOLD LACE MANUFACTURE; of *China-gilding*, under PORCELAIN; and of *Book-gilding*, under BOOKBINDING.

Metal-gilding. The process of metal-gilding is one of the most delicate in the manufactures in metal; seeing that its success depends on a nicety of eye, a dexterity of hand, and a practical acquaintance with the chemical operations involved in it, which cannot be acquired without several months' or even years' experience. Mechanical errors and difficulties are in most cases detected and remedied with much greater facility than those which arise in the chemical branch of manufactures. To these latter the processes of gilding and colouring are particularly subject, and more especially that of gilding.

The gold made use of for the purpose of metal-gilding is called "fine gold," and is perfectly free from alloy. Its form is that which, in metals, is usually termed "shot," from its having been poured or shot when in a fluid state, into cold water. This operation divides it into pieces of various shapes and sizes, from the smallest grain, scarcely perceptible by the naked eye, to the dimensions of a pea or a nut. This form of the metal is best adapted for the gilder's purpose.

The union of the gold with the metal to be gilt is effected through the agency of mercury. The gold and mercury are first combined, by boiling the former in about five or six times its weight of the latter. These proportions are put into an iron ladle, which must have been previously lined with a coating of whiting and water, and then carefully and thoroughly dried. Should there be any moisture left in the lining, or if any cracks should expose the naked surface of the iron, the ebullition of the mercury is so rapid there, owing to the more rapid conduction of the heat, that a portion of the amalgam would be thrown out by the violence of the action. It is most economical to place the ladle and its contents within the heated iron cylinder used for the evaporation of the mercury from the articles when gilt, by which arrangement a considerable portion of the mercury which is evaporated during the process is retained by the condensers. The time necessary for dissolving all the gold in the mercury varies according to the hardness or softness of the gold (that which has been more *annealed* by the refiner appearing browner than the harder and yellower, and requiring a longer time for complete solution), and according to the larger or smaller size of the fragments of gold made use of. In general, half a troy pound of gold is completely dissolved by being kept at the boiling temperature of mercury for about twenty or twenty-five minutes. It is obvious that the boiling should be as gentle as possible, since fast boiling ensures no higher a temperature, and evaporates a greater quantity of quicksilver.

When it has been sufficiently boiled, the amalgam is poured out into cold water, by which it loses a great part of its fluidity, and becomes semi-fluid; the consistence depending, of course, on the quantity of quicksilver originally made use of, and the proportion of it that has been evaporated. The amalgam is then put into a piece of chamois skin, and squeezed; by which means the particles of quicksilver escape through the pores of the leather, while those of the gold are safely retained. When the mass is felt to be hard and unyielding within the leather, it is weighed, and its value is determined by considering five parts by weight of the amalgam as equal to one part by weight of the gold employed. The amalgam then, if good, is of about the consistence of a stiff clay, has a greasy and gritty feel on being divided by a bone spatula, and is in the most convenient state for being weighed out into the portions requisite for each respective quantity of work. If however the gold be adulterated or the mercury be impure, the amalgam often approaches more or less to fluidity, appears dirty, and deposits a black adhesive scum on every thing with which it comes in contact. The main object of bringing the amalgam to this consistence and these proportions is to have it in a form convenient for division and apportionment, as well as for the sake of having a uniform standard by which to ascertain the quantity and value of the gold employed. As, however, this consistence is not adapted for being applied to its intended purpose, without a greater or less dilution by being again boiled for a short time in mercury, many metal-gilders, especially those who provide their own gold, prefer to weigh out the gold which they intend to use, and then to mix it at once with the quantity of quicksilver which experience has taught them to be proper and necessary, and which varies according to the nature of the articles to be covered with it; for such articles as are wrought into deeply indented or highly ornamented patterns, or which are to have their surfaces completely covered, require a more fluid amalgam than those which have a smoother superficies, or which are to be only partially gilt.

On the application of this amalgam to the surfaces of copper, brazen, or mixed metal articles, it is found that, as there is no chemical affinity, and consequently no principle of mutual cohesion, between the substances thus brought into contact, the direct union of them is impossible. Nor can it be effected by allowing them to remain in contact for any length of time. The intervention of a solution of nitrate of mercury is therefore used. This salt is made by pouring a table-spoonful of quicksilver into about a quart of strong nitric acid, which is termed in commerce "gilders' aquafortis;" the red fumes of nitrous gas are instantly evolved, and the mercury is rapidly united with the acid, with the production of considerable heat. This solution is, by the unscientific operatives, termed "quick-water," the monosyllable "quick" being, in their language, a sufficient representative for the more tedious appellation of "quicksilver;" and the workshop name of this liquid has caused the appellation of *water-gilding* to be given to that which would more properly be called *metal-gilding*. When it is uncontaminated by the presence of any foreign substance, the "quick-water" is white and pellucid.

When a piece of copper or brass is immersed in or brought in contact with this solution, its surface is immediately converted into an amalgam. To this amalgamated surface mercury and gold amalgam closely adheres, by means of the molecular attraction of the particles of the fluid metals for each other.

The manner in which this agent is applied in practice varies according to the kind of articles about to be gilt. If they are small, strong, and to be gilt all over, as copper buttons, buckles, and rings, a quantity of them, which should not exceed three or four pounds in weight, is put into a deep glazed earthen pan or "jowl;" to these are added about three or four tea-spoonfuls of the "quick-water," together with the requisite portion of amalgam. The whole is then thoroughly stirred with a brush or stick, till the amalgam entirely covers the surface of every article, more particularly the indentations and sunken parts, which are the last to receive a coating, from their being less exposed to the contact of the fluids. When they are completely covered, they are by some gilders rinsed in cold water and dried by shaking in a bag of warm sawdust; while by others this part of the process is postponed to a later period of the operation, and they are put, in their wet state, with the generated nitrate of copper still hanging about them, into the gilding-cage. This cage is made in a cylindrical form, and is generally about 18 inches in length by 9 or 10 in diameter. It is formed of coarse iron-wire gauze, supported by an external framework of iron, and furnished with a solid iron door at one extremity, which generally forms a sector of one-third of the circular end. It is provided with an axle, which extends to a length of about 3 feet from the end at which the door is placed, and is there terminated by a winch, and to a distance of 5 or 6 inches in the opposite direction. The articles under process of gilding are placed in this cage, and the door of it securely fastened; it is then suspended by its axle on two supports in an iron cylinder, which somewhat resembles a gas retort, and which is in a similar manner fixed into brickwork over a furnace or stove. The cylinder being previously heated by a coal fire beneath it, to such a degree as to be red-hot over a large proportion of its inferior surface, the cage is introduced, and the doors of the cylinder closed. The heated air contained within the cylinder soon raises the temperature of the substances immersed in it; and as the cage is kept continually revolving by means of the winch, which projects through an aperture in the doors, they have all an equable share of heat, and allow of a nearly equal evaporation of the mercury from all their surfaces. The farther extremity of the cylinder communicates with a chamber, which is in general built of masonry and plastered over all the internal surfaces. The floor of this chamber is covered to a depth of about two feet with cold water, which on coming into contact with the mercurial vapours condenses a portion of them, and causes them to return to the liquid form. If this condenser, however, were made quite close, a great portion of the mercurial vapour would return through the cylinder into the apartment or gilding shop, and thus not only be wasted, but materially injure the health of the persons engaged in the work. A communication extending obliquely upwards, and made of one or more ranges of iron stove-piping, is therefore connected with a second smaller condenser on the story above, and this is again repeated a third or perhaps a fourth time. A current of heated air is thus continually ascending from the lowest condenser, and establishes a perpetual draught through the cylinder, thus preventing the deleterious mercurial vapour from mixing with the atmosphere of the shop in which the work is going forward; some of the vapour is, however, necessarily wasted by this precaution. The condensers are opened at intervals of several months, and the quicksilver taken out, washed, and dried; it is sometimes found necessary again to distil it, to free it from all impurities.

After the cage, with its contents, has been in the cylinder for a length of time varying, according to the temperature at which it has been kept, from five minutes to a quarter of an hour, the mercury will be found to have entirely evaporated from the gilt surfaces. If the articles have been previously washed and dried, they will appear of a clear yellow colour; and they may be allowed to remain in the cylinder, the cage revolving as before, until they are sufficiently heightened in tint. If they have not been so treated previously, they will appear of a dark, soiled, dirty colour, being covered with an incrustation of oxide of copper and of iron, and other impurities. To remove these, the goods are taken out of the cage; and after being allowed to cool for a few minutes, they are thrown, while still warm, into weak quick-water, that is, diluted nitrate of mercury. This converts the gold again into amalgam, owing to the precipitation of a portion of the mercury by the copper, which is taken up with avidity by the gold. They are then washed with clean water, dried in warm sawdust, and again committed to the cage and cylinder, which, by the evaporation of the mercury, give them a clean colour. They may then be heightened, which is done by continuing to revolve them at the same high temperature within the cylinder, occasionally shaking them together, that they may all have an equal share of the heat. The end intended to be effected is a partial oxidation of the surface of the gold, caused by means of the increased temperature of the metal goods after the mercury has evaporated, and which remains unaffected by nitric or sulphuric acids after the slight film of oxide of copper has been instantaneously removed by their action. This partial oxidation occasions a slight difference of colour, which is perceptible to an experienced eye, and confers on the gold a degree of that orange colour which is so generally admired in golden and gilt articles.

Buttons and articles of a similar description are often gilt only on their tops, or on some other portion of their surfaces; while the remainder is left uncovered with gold, and of the native colour of the metal of which they are manufactured. This is accomplished in the mode described under BUTTON MANUFACTURE.

Many descriptions of articles would be injured or destroyed by the method of gilding just now described. Such are all those which are of considerable dimensions in proportion to the thickness of the metal out of which they are made; as well as those whose individual weight and extent of surface would expose them to such attrition from the rotatory motion of the cage as would occasion the gold laid on to be entirely or partially rubbed off in the process of its application. Besides this, there is in thin and fragile articles an imminent danger of their being broken when they are amalgamated and rendered brittle throughout a great part of their substance by the necessary immersion in the quick-water. To obviate the inconveniences that might hence result, a different method is employed, so far as regards the mechanical part of it, though the chemical principles on which it depends are precisely the same. Articles of this description are most commonly gilt only on one side. There are two modes of preventing the amalgam from adhering to those parts of the surface that are intended to be left bare. One is to lacquer those parts, and after the spirit of wine is thoroughly evaporated, to immerse them in the quick-water, and afterwards apply the amalgam; the gummy surface left behind by the lacquer is entirely unaltered by its contact with the mercurial solution; but its exposure to the high temperature necessary in the subsequent parts of the process chars the gum, blackens it, and causes it to peel off. The other mode of applying the gold is to distribute the quick-water over the parts requiring it by a small brush or camel's hair pencil, and these then have the amalgam applied as before; if, as is sometimes the case, the goods are to be entirely covered, they are immersed at once in the quick-water. The goods thus prepared are laid with the gilt surfaces uppermost on an open iron pan, of a shape something like that of a frying-pan, which is held over a coke fire. The chimney is made wide at the bottom, and narrows rapidly as it proceeds upwards, so as to collect as much as possible of the mercurial vapour, for the recovery of which no effort has hitherto been made. A great proportion however necessarily escapes into the apartment, and renders this mode of gilding much more unhealthy than the use of the cylinder and cage. As the mercury gradually evaporates from their surfaces, their position is changed, when requisite, by means of a short pair of tongs; and when entirely free from it, the process of quick-watering is performed.

Where the cylinder is employed, it is usually swept out daily, before the fire has heated it in the morning. A portion of the gold amalgam is rubbed off by the attrition of the cage, and falls on the interior surface of the cylinder, whose heat melts it wholly or partially, and it becomes mixed with the oxide of iron that is constantly in course of production by the elevated temperature of the cylinder. This being carefully collected and refined, is found to yield an average of about 1-30th of the gold employed, to which dividend the richer sorts have contributed from their superabundance a greater proportionate quantity than the commoner qualities.

Gilt articles of all the better qualities are submitted to an after-process called colouring, for the purpose of conferring on them a deeper orange tint than is natural to the gold itself, or can be obtained by the process of heightening already mentioned. The principle of this additional operation is always the same, though the methods resorted to differ greatly from each other. One of the compositions employed for this purpose is formed of twenty-four parts of nitrate of potash, ten of sulphate of alumina, five of sulphate of iron, and five of sulphate of zinc, boiled together in water, thoroughly mixed, and cooled without being allowed to crystallise. This mixture is formed into a thin paste with water, which is spread over the surfaces of the articles by their being immersed in it; and when they are placed on a heated iron plate, the warm gold surfaces become oxidised. A mixture is sometimes made of bees' wax and yellow ochre, which being rubbed over the gilt surfaces and burnt off, occasions on a similar principle the same result. Goods that are to appear bright are scratched over before colouring with a brush made of fine brass wire.

Most gilt articles are burnished by a stone burnisher, formed of a polished piece of black hæmatite. This is fixed into a proper handle. Small articles, as buttons, &c., are placed in a lathe, and the stone applied to them as they revolve; those that do not admit of this are burnished by hand on a table or bench.

Besides copper and brass, several other substances admit of being gilt. Silver is gilt in a manner similar to that above described. Steel and iron are gilt by being immersed in a mixture of the nitro-muriate (or more properly the chloride) of gold with sulphuric ether or alcohol. By combining these liquids together, an alcoholic solution of gold is formed, from which the metal is precipitated by the iron or steel. Many applications of gilt metal are now superseded by the remarkable electrotype process in the way described in the article already adverted to.

Wood-Gilding. Wood work, whether plain or carved, is gilt by the following processes. Parchment-size is dissolved in water by heat, and a little whiting mixed with it. This composition is brushed over the picture-frame or other article to be gilt. The holes and cracks that may be in it are then filled up with a mixture of the same ingredients in different proportions, and of about the consistence of putty. A composition of the same sort, but containing more whiting than the first, is then brushed over it, and allowed to dry. This is repeated several times, till a considerable thickness has been laid on. The plain parts are then moistened, smoothed down with pumice stone and water, hard stone and water, Dutch rush, glass paper, and other substances; and the corners and mouldings are squared and shaped by proper tools. When dry the work is covered with several coatings of gold-size, a peculiar composition, of which deer's fat is said to form the principal ingredient. The frame or other article thus prepared, is placed in a sloping position; its parts are successively moistened with water; gold-leaf is laid on them by a "tip" (a sort of comb formed by inserting a row of camels' hairs into a card), and is pressed down into the cavities by a dry camel's hair pencil. The gold when dry is burnished by a stone in some parts; while others are left *mat* or dead, and are protected by a varnish of very clear size.

This constitutes *burnish-gilding*. *Oil gilding* differs from it chiefly in the use of a gold-size of an oily nature, which admits of no burnishing of the gold. *Japan-gilding* is a third kind, in which Japan gold-size is used, for work intended to be exposed to the weather.

The applications of gold-leaf to leather, paper, wood, and other substances, are numerous and diversified; but what has been said above will be sufficient to indicate the principles and details of this branch of the arts. It may be well to add, that glass may be gilt by the following simple method:—Dissolve some isinglass in water by means of heat; evaporate the liquid, and allow it to crystallise. Re-dissolve some of the crystals, and after making the mixture of the usual consistence of glue, dip into it a piece of clean chamois leather, which is to be drawn once, and only once, over the parts of the glass that are to be gilt. Lay on the leaf-gold, which will adhere, and allow the whole to dry. On this coating of gold another may be placed in a similar manner, being careful to draw the isinglass only once and lightly over the former coating. It will be generally found advisable to repeat this process a third time. Any superfluous gold may be removed by a sharp stick, and the gilt parts are to be polished by rubbing them with clean cotton, which will obliterate all traces of any joinings, and prevent them from being visible from either side of the glass.

GIN. [Cotton; Geneva.]

GIN, or **GYN**, a machine employed instead of a crane, chiefly by artillerymen, for the purpose of raising guns, howitzers, &c., on their carriages. It consists of three round poles, from 12 to 15 feet long, and 5 inches in diameter at the lower extremity, tapering to about 3½ inches at the top.

The three poles are, by means of an iron bolt passing through straps, or by a rope passed several times round each, united together at their upper extremities in such a manner that they may be turned about their place of union; and when the machine is set up, the feet of the poles are planted in the ground at about 8 or 9 feet from each other. The feet of two of the poles are kept at that distance by means of a rope or an iron bar, which may be temporarily placed in a horizontal position near their lower ends; and between the same two poles, at about 3½ feet from the ground, is a wooden roller, or windlass, which, by means of handspikes, may be turned on its axis, the pivots entering into holes sunk in iron cheeks attached to the poles. The third pole, commonly called a "pry-pole," has a greater extent of movement than the others about the upper extremity, so that all the three poles, previously to being set up, may lie on the ground. The gyn is then set up over the object to be moved; two blocks with their *fall*, or rope, are employed in raising or lowering the gun, the upper block being fixed to the top of the poles, and the other, by means of a rope, to the piece of ordnance: the rope from the upper block passes over the windlass before mentioned.

Two poles fastened together at the top, and set up like the sides of the letter A, the whole being kept steady by means of ropes made fast to the upper extremity and to strong pickets driven into the ground, are also employed for raising or lowering artillery, by means of two blocks with their rope, the extremity of the latter usually passing round the cylinder of a windlass, capstan, or crab. This apparatus is called sheers.

GIPSIES. [Gypsies.]

GIRDERS. The timber or iron beams, employed in building operations to carry loads over large openings, are known technically by the name of *Girders*, either simple or framed. The former will alone be noticed here.

A simple girder resists the action of the weight brought upon it by its inherent transverse strength, and it must be evident to any one who would observe the manner of fracture of any such beam, that the fracture is produced by the extension of the lower fibres, and by the compression of the upper ones, whilst the intermediate part of the beam plays but an insignificant part in its resistance, so long as the upper and the lower portions are not overstrained. Theoretically, then, the middle parts of a beam might almost be eliminated, because they not only do not render any service, but they actually tend to increase the load by their weight; but, from the physical nature of the materials usually employed as girders, it is hardly possible to attain this condition, and the efforts of the constructors are therefore limited to the attempt to approach, as nearly as may be, to the form of a girder of the maximum resistance with the minimum quantity of material. This form varies with every description of wood, or of iron; but the character of the growth of timber renders it unnecessary to pay much attention to the varying resistances of its fibres to compression or extension; whilst, on the contrary, it is easy to modify the disposition of the metal, whether wrought or cast, so as to call into play its various properties under the most economical conditions.

The strength of a simple timber girder is found, experimentally, to increase directly as the width, and as the square of the depth; or, if a beam of 6 inches on the sides bear a certain weight, two such beams will bear twice that weight, and a beam of twice the depth will bear four times the weight; the strength is likewise inversely as the length. These ratios are usually expressed by the formula $\frac{b\,d^2}{l}$, in which $b =$ the breadth, d the depth, and l the length; and it requires simply to be modified by a coefficient, dependent upon the specific strength of the kind of timber under consideration, to furnish a correct indication of the powers of resistance of a girder; or the breaking weight in pounds of a girder will be represented by $\frac{b\,d^2 c}{l}$, in which the new term, c, is the constant of the wood. Barlow, Nelson, Moore, and Dennison give, in the papers of the Royal Engineers, a table of constants which is now generally adopted; and from the fact that the results it indicates are considerably within the real capabilities of the various woods, there seems to be no reason for objecting to it:—

Kind of Wood.	Sp. gr.	Value of c.	Kind of Wood	Sp. gr.	Value of c.
Ash, English . .	·760	506	Pine, American, yellow .	·508	300
,, American . .	·626	450	,, ,, pitch .	·740	432
Beech, English . .	·696	390	,, Danzig . .	·649	356
Birch, common . .	·711	482	,, Memel . . .	·601	334
Cedar of Lebanon . .	·330	373	,, Riga . . .	·654	346
Elm, English . . .	·579	200	Fir, spruce . . .	·503	336
Hickory . . .	·831	532	,, ,, American .	·772	260
Oak, English . . .	·829	424	,, Mar Forest . .	·698	308
,, African . .	·988	630	Deal, Christiania . .	·689	400
,, American, white .	·779	433	Larch	·505	256
,, ,, red .	·952	422	Tamarak . . .	·433	230
,, Danzig : . .	·720	377	Mahogany . . .	·668	430
,, Memel . . .	·727	416	Teak	·729	527
Pine, American, white .	·432	307	Vancouver's Island fir, one experiment only	..	728
,, ,, red .	·576	382			

The manner in which a load is applied to a beam, it must however be observed, considerably modifies its resistance; for if the load be distributed equally over the whole length, the beam would carry twice as much as it would do if the load were concentrated in the centre. Again, if the ends of the beam be fixed, the breaking weight it would carry would be increased, upon the average, nearly in the ratio of 2 to 1. The values of c, given above, have been ascertained from the results of experiments on beams whose ends were loose; but as the effect of a permanent load (in producing fracture) is so markedly greater than that of an instantaneous load, it is not customary to take into account the increase of resistance of girders through the tying down of their ends, which in fact almost always occurs in building operations. The values of the above table are the instantaneous breaking weights of the average qualities of the woods named, and therefore the weight actually placed upon them should never exceed one-third of the amount they indicate; or, in other terms, the safety load of a beam should never exceed one third of the breaking weight. Buffon states that he had found that beams would break at the end of six months under two-thirds of the load they might be able to support for one day. It is essential also to observe that the character of the load will affect the resistance; for a dead weight produces a far less injurious action than would be produced by a rolling or a variable weight; and that the various kinds of wood yield in very different manners. Some of them deflect in an extraordinary degree, whilst others change but slightly in their outlines, and break suddenly, without warning, after their limits of elasticity have been exceeded.

The form of beams which is able to do the maximum amount of work with the minimum amount of substance is usually considered to be, according as the beam is supported at one or at both ends (Warr's 'Dynamics,' 1851), as follows:—For beams supported at one end; 1. *a.* If the load be constant, and applied at the extremity, and the depth of the beam be also constant, the transverse section should diminish gradually from the point of support towards the extremity; *b.* If the breadth be constant, the depth should vary as the length; if both breadth and depth vary, the vertical section should present a cubical parabola. 2. If the beam should only have its own weight to support, it should present in vertical section a double parabola, whose depth should be as the square of the length. 3. If the beam should be evenly loaded upon its surface, and the upper surface be horizontal, the lower surface should be a straight line meeting the upper surface at the extremity; the depth at the point of support being the one required to resist the effort of the load and of its leverage; and if an additional load be placed at the extremity of the beam, the under surface should present a parabolic curvature.

For beams supported at both ends:—1. If the beam be loaded at only one point, it should present a parabolic vertical section, falling each way from the loaded point. 2. If the beam be loaded uniformly, the upper surface should be elliptical, and the lower one straight. 3. In flanged beams evenly loaded, the upper surface should be made parabolic instead of elliptical, and the sides of the flanges in plan should also present a parabolic curvature.

In modern construction the openings between the points of support and the loads to be supported, are often so far in excess of the powers of wooden beams that it is necessary to resort to the use of iron in one or another of its forms; and, practically, this is effected by the use of some modification of the flanged section. Numerous experiments have been made for the purpose of ascertaining the best proportion to be given to metal girders, a description of which will be found in Warr's 'Dynamics' before quoted; in Barlow, on 'Materials and on Construction,' 1851; Moseley's 'Engineering and Architecture,' 1843; Weisbach's 'Mechanics of Engineering and Machinery,' 1848; Tate, on the 'Strength of Materials,' 1850; Fairburn, on 'Cast and Wrought Iron for Building Purposes,' 1854; Hodgkinson's new edition of Tredgold, 1856; Morin, 'Leçons de Méchanique Pratique,' 1846, &c. &c. From these authors it would appear, 1st, that the power of cast-iron to resist a tensile strain is, when compared to its power of resisting an effort of compression, as 1 to about 5·707; 2nd, that the strength of cast-iron girders is nearly in the direct ratio of their bottom flanges; 3rd, that everything else being equal, the strength is nearly as the depth. Mr. Fairbairn resumes the inquiry into the best form of iron girder by giving the following formula for ascertaining the breaking weight: $w = \frac{c\,a\,d}{l}$, in which w = the breaking weight applied in the centre; a, the area of the bottom flange, which is made 6 times that of the top one; d, the depth of the beam in inches; l, the distance between the supports in inches; and c, a constant, ascertained experimentally to be $= 26$. In the best cast-iron girders the proportions of the other respective parts than the top and bottom flanges are, *a.* the width of the bottom flange is made rather less than half the depth of the girder in the centre; *b.* the thickness of the centre web is made equal to one half that of the bottom web, when that theoretical condition can be attained without compromising the solidity of the casting, or the quality of the metal.

Compound cast-iron girders, in which the strength is obtained by a combination of the resistances of cast and wrought iron, have been found practically to be liable to so many objections, on account of the different physical properties of the two states of the metal, as to have led to the abandonment of their use. Cast-iron beams are frequently cast in lengths of 40 feet, and even occasionally of 70 feet, though at some risk. Beyond those lengths, it is necessary to resort to the use of either the arched construction, if cast-iron be used, to some description of framed girder, or to the use of wrought iron.

In wrought-iron girders it is found that the proportionate resistance of the top and bottom flanges to the efforts of compression and extension differ notably from those which were previously stated to prevail in cast-iron; for the resistance of wrought iron to compression is only one half of its powers to resist extension, and the top flanges of wrought-iron girders, therefore, should be made about double the sectional area of the bottom flanges, instead of being as in cast-iron girders only $\frac{1}{6}$ of that dimension. Mr. Fairbairn gives the formula for the breaking weight of a wrought-iron girder, as follows; $w = \frac{a\,d\,c}{l}$, in which the same notation is followed as in the formula for cast-iron girders; but singularly enough in working out his examples, instead of making a = the *area* of the bottom flange, he attributes to it a value derived from the *width*. The coefficient, c, becomes, according to Mr. Fairbairn, 75, when ordinary plate-iron girders are used, and 80, when boxed girders are adopted; and, from the experiments he records, it would seem that the coefficient of a lattice girder is nearly the same as that of a plate girder. Exactly, it would appear to be 72. One of the best rules for proportioning box girders is, firstly, to make the area of the top equal to twice that of the bottom; to make the thickness of the sides from $\frac{1}{70}$ to $\frac{1}{300}$ of the depth of the tube, according to the facilities for giving it lateral stiffness; and then, as the span and the depth are often given, to calculate the dimensions of the bottom flange from the ratio, $s : d :: s : w$; in which s = the span; d = the depth; s = the cohesive strength of the bottom flange, calculated on the assumption that it is equal to 15 tons on the superficial inch; and w = the breaking weight in tons. This would, of course, give the weight under which the girder would instantaneously break, and it should therefore never be approached in practice. Indeed, if the girder should be exposed to rolling weights, or to sudden shocks, it should present a resistance at least six times that of the maximum load able to produce instantaneous fracture.

The above remarks have been designedly made as practical, and as devoid of abstract theory as possible, leaving that part of the investigation to RESISTANCE OF MATERIALS; NEUTRAL AXIS; TUBULAR BEAMS. The reader who may desire to study the theory of the subject is, moreover, referred to the author before quoted; or to Clark's 'Britannia and Conway Tubular Bridges.' Framed girders are described under TRUSS.

GIRDLE, a band of leather, or some other substance, to gird up the loins: from the Anglo-Saxon *gyrdel* or *gyrdl*, and that from *gyrdan*, to encircle or bind around. Girdlestead is an old English word for the waist, or place of the girdle.

There are many passages in Scripture, as well as among the Greek and Roman writers, illustrative of the girdle. It appears to have been rarely worn by the Hebrews, except upon a journey. Elijah, we are told, girded up his loins, and ran before Ahab. Girdles of sackcloth, too, were used among the Hebrews as marks of humiliation and sorrow.

As a military ornament, it is noticed in Homer ('Il.' iv. 135; v. 539, &c.); and so universal was its use among the Greek and Roman warriors, that Pitiscus, in his Lexicon, says, "Et *Cingulum* pro ipsa militia usurpatur." Military girdles were often given as rewards for bravery. The magister equitum of the Romans wore a red girdle as a distinctive badge.

A girdle, or zone, was always worn by young women before marriage. Hence, "Zonam solvere virgineam," to loose the maiden's girdle, in the language of Catullus, was a phrase appropriate to the marriage ceremony. Festus says, "Cingulum quo nupta cingebatur vir in lecto solvebat." This girdle was usually of wool. The cestus of Venus was the zone or girdle. It was worn round the lower part of the waist, and concealed by the falling of the tunic.

The term girdle was in ancient times very frequently used to express the purse. An epigram in the 'Anthologia' shows that this was the custom among the Greeks; and it is in this sense that we must understand the fragment of Gracchus's speech to the senate, upon his return from Sardinia, quoted in Aulus Gellius, lib. xv., c. 12: "Itaque Quirites, quum Romam profectus sum, zonas, quas plenas argenti extuli, eas ex provincia inanes retuli."

In Mark vi. 8, when our Saviour sent his Apostles out to preach, he commanded them to take no scrip, no bread, no money in their purse: the Anglo-Saxon version reads, *ne fesh on hyra gyrdlum*, "nor money in their girdles." Hence probably arose the custom, formerly used in England, for bankrupts or other insolvent persons to put off and surrender their girdles in open court.

Various passages in the classic writers might be adduced to show that to go without the girdle was considered disreputable, and bespoke a dissolute person. Aubrey, in one of his manuscripts, says that "Ungirt, unblessed," was an English proverb before the civil wars of Charles I.

Among the ancient companies of London, that of the Girdlers was incorporated as early as August 6, 1449, 27 Henry VI., and it has been supposed that these were the makers of girdles. Their armorial ensigns are, "Per fess, az. and or, a pale counter-changed, each piece of the first charged with a gridiron of the second. Crest, the demi-effigy of St. Lawrence, holding in the right hand a gridiron, and in the left a book." Strype, in his edition of Stow's 'Survey,' conjectures, from their arms, that the girdlers were originally a fraternity of St. Lawrence. But, as Mr. Thoms, in his edition of Stow, suggests, these arms seem to indicate pretty clearly that the girdlers were really makers of the girdles, or griddles, still used for baking oaten cakes in every household in Scotland and much of the north of England.

GIRONDINS was the name given to a political party which formed a section of the second National Assembly of France, called "Legislatif," in contradistinction to the first or "Constituante," which framed the constitution of 1791. The members of this party were mostly returned by the departments of the west and south; and as their leaders, Vergniaud, Guadet, Gensonné, &c., represented the department of La Gironde (Bordeaux), the party took the name of Girondins. They showed themselves from the first hostile to the monarchy, and they stood opposed to the constitutionalists, who wished to maintain the constitution of 1791. The Girondins were republicans, who had formed notions of liberty on classical models, such as they were then conceived by ardent young men. They had among them some brilliant orators, and several accomplished and amiable individuals; but as a political party they placed themselves in a false position, and they did great mischief to others. By their opposition to the constitutionalists they weakened the strength of the middling classes, and left the field open to those who, like Danton, addressed themselves to the passions of the lower orders. They at one time obliged the king to choose a ministry from among themselves, including Roland, Servan, Clavière, and Dumouriez, and they seemed for awhile reconciled to the constitutional monarchy; but a schism broke out among them, and they resigned. Soon after came the scenes of June and August, 1792, which the Girondins indirectly sanctioned, and which destroyed the monarchy in France. In the Convention the Girondins for the most part voted for the death of the king; they tried indeed to obtain a reprieve for him, but in this they failed. They then began to feel their weakness; they struggled for several months against the ascendancy of the Montagne or Terrorist party, which was supported by the mob; the Girondins wished for legal forms, they denounced the popular massacres, but they had no support out of doors to depend upon. At the same time they excited the republican enthusiasm of the French, and it was Brissot, one of their leaders, who proclaimed the principle of democratic proselytism, afterwards sanctioned by the Convention, by its decree of the 17th of December, 1792. But this turned to the profit of the Terrorists at home, who were the men of the lower classes, which the Girondins were not. The latter endeavoured to create an opposition in the departments, to counterbalance the influence of the Paris demagogues, but they were denounced as wishing and conspiring to split France into as many republics as there were departments. At last, on the 31st of May, 1793, the Convention was assailed by armed multitudes, demanding the imprisonment of twenty-nine deputies of the Girondin party. The Assembly was obliged to give them up, and on the 31st of October following twenty-one of them were executed, including Vergniaud, Gaudet, Gensonné, and Brissot. Others were beheaded afterwards. A few escaped, and reappeared again in the Convention after the fall of Robespierre. Dumont, in his 'Recollections of Mirabeau,' ch. 18–20, gives some vivid sketches of several of the leaders of the Girondins; and Lamartine has written a 'History of the Girondists.'

GITHAGIN, a peculiar kind of Saponin, obtained from the corn lychnis (*Lychnis githago* and *Agrostemma githago*). [SAPONIN.]

GLACIS, an elevation of earth surrounding a fortress on the exterior of the covered-way, to which it serves as a parapet. [s, s, *fig.* 1, BASTION.] Its crest is eight feet above the terreplein of the covered-way, and its superior surface, which descends with a gentle slope towards the country, meets the natural ground at about fifty yards from the covered-way.

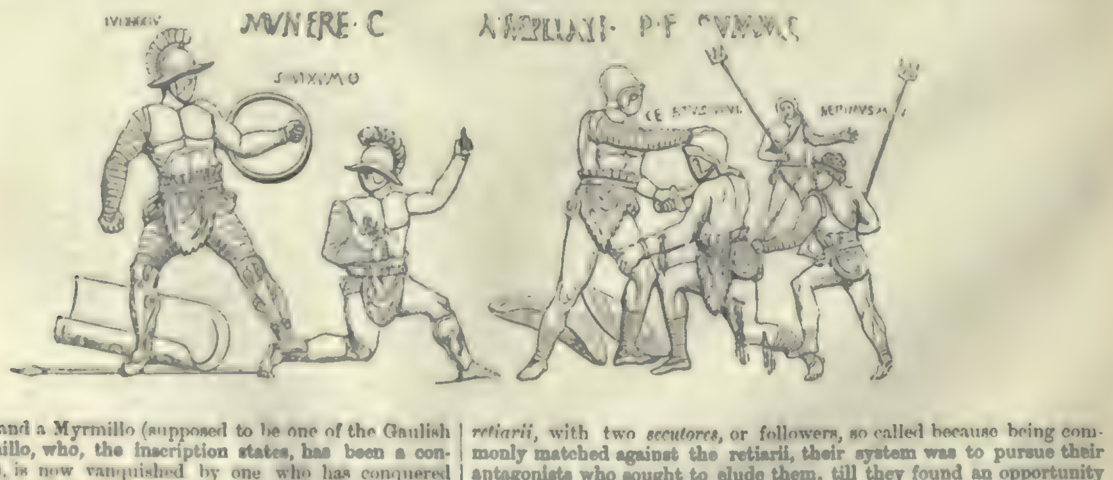
The glacis conceals the upper part of the masonry of the escarp from distant breaching batteries, and by forming an inclined plane ascending towards the fortress, serves to expose the approaches of the besiegers, when they arrive near the place, to the fire of artillery from the bastions or ravelins; and a banquette, or step, at the foot of its interior slope, enables the defenders to graze its superior surface by a fire of musketry, and gives the further defence of another line of simultaneous fire.

Any elevation of earth beyond the ditch of a fortress, and forming an inclined plane descending towards the latter, is called a reverse or counterslope glacis.

GLADIATORS were men who fought with swords, 'gladii,' and other weapons, and wounded and killed one another in the circus, the amphitheatre, and other public places, for the entertainment of the Roman people. They were either slaves, prisoners or convicts, and as such obliged to fight; or volunteers, who exhibited for money. There were establishments in the Roman towns, in which the gladiators were boarded and taught their art, and in which a certain number of those who had been trained were always kept in readiness for the fight. Their master and keeper was called Lanista. Gladiators were classed and named according to the weapons they used, and their manner of fighting: thus *Ordinarii* were those who fought in pairs in the ordinary way; *Catervarii*, those who fought several together; *Equites*, those who fought on horseback; *Retiarii*, those who used a sort of fork called a tridens, and a net which they threw over their opponent, who usually carried a short sword and shield; *Andabatæ*, who fought blindfold, their heads being covered with helmets which had no apertures, and whose manœuvres were consequently exceedingly ludicrous; *Hoplomachi*, who fought in complete armour, &c. All bore armour on the right arm, if nowhere else; and except the Retiarii, wore helmets, and carried shields. The *Bestiarii*, who fought with wild animals for money, were not ranked among the gladiators. When a wealthy man wanted to give a gladiators' fight, either at a funeral or on any other public or private occasion, he bargained with the Lanista for a certain price to give him so many pairs of gladiators. Out of each pair one was to die, if so required by the spectators. Palms were given to the victors. When a gladiator was severely wounded, so as to be unable to fight any longer, his antagonist stood over him with his sword ready to kill him, and looked up to the assembly for its fiat. If the majority turned their thumbs downwards, that was the signal of death. The origin of this barbarous custom seems to have been derived from the practice of killing a certain number of captives at the funeral of a chieftain. Homer represents Achilles as sacrificing twelve young Trojans at the funeral of his friend Patroclus. Afterwards, instead of butchering the prisoners like so many cattle, it was thought better to make them fight round the funeral pyre, when the conquerors had a chance of escaping with their lives. By degrees the custom was extended to all great festivals, for the amusement of the spectators, and the waste of human life thus wantonly sacrificed was increased to a fearful extent in the later times of the Roman republic and under the empire: on the occasion of Trajan's triumph over the Dacians 10,000 gladiators are said to have fought. The practice was defended even by grave men, and Cicero among the rest, as serving to keep up a martial spirit and a contempt of death among the people. It certainly contributed to render the people ferocious and cruel. Constantine prohibited gladiators' fights by an edict ('Cod.' xi., tit. 43), but the practice, it is said, was not totally extinct in the West till the time of Theodoric. The Greek republics did not adopt the custom of gladiators' fights. It was a practice essentially Roman, and the Romans are said to have adopted it from the Campanians, who had gladiators' fights even at their banquets. (Lipsius, 'Saturnalia;' Ferrari Octavius, 'Dissertatio de Gladiatoribus.')

Rome was at one time near paying very dearly for this inhuman pastime. In the year 76 B.C. seventy-four gladiators at Capua rose against their master, overpowered the guards and fled to the mountains, where they were joined by runaway slaves and peasants, to the number of several thousands. Being led by a gladiator of the name of Spartacus, a Thracian by birth and a man of superior abilities, they defeated several Roman armies, overran Campania, Lucania, and other provinces, took and plundered Nola, Nuceria, and other towns, and spread alarm almost to the gates of Rome. But dissension grew up among their ranks. One portion of them, chiefly Gauls, separated from the rest under one Crixus, and were defeated and cut to pieces by the consul Gellius. Spartacus, who was on his march towards North Italy, having retraced his steps on hearing this news, defeated Gellius, as well as the other consul Lentulus, and then fortified himself in the mountains of Lucania. He performed a solemn funeral in honour of Crixus, who had fallen in battle, and obliged 300 Roman captives to fight as gladiators round the pyre. The war lasted three years, at the end of which Spartacus was defeated by the prætor M. Crassus, and was killed after performing prodigies of valour. (Livy, 'Epitome,' 95–97; Eutropius, vi. 6.) [CRASSUS, in BIOG. DIV.]

There are several ancient statues, highly praised for their workmanship, which represent or are supposed to represent gladiators in several attitudes. One of the best is the 'Fighting Gladiator' of the Borghese collection, now in the Museum of the Louvre. The 'Dying Gladiator' of the Capitoline Museum has furnished Byron with the subject of one of the finest stanzas of his 'Childe Harold:' "I see before me the Gladiator lie." In the tomb of Scaurus at Pompeii is a series of bassi-relievi, which aided by the inscriptions placed above each group, illustrate very clearly the manner of fighting of the gladiators. The annexed cut is from a portion of the upper frieze. The pair on the right are a Thrax (Thracian) and a Myrmillo (supposed to be one of the Gaulish tribes). The Myrmillo, who, the inscription states, has been a conqueror fifteen times, is now vanquished by one who has conquered thirty-four times; he begs his life, but the letter Θ (the initial of θανων) indicates that he was to be put to death. The other group are two *retiarii*, with two *secutores*, or followers, so called because being commonly matched against the retiarii, their system was to pursue their antagonists who sought to elude them, till they found an opportunity to cast the net. In this case, a secutor has been defeated, and pleads for mercy; the spectators however have turned down their thumbs, but as



the trident with which the retiarius is armed is not a weapon fitted for speedily despatching a man, the poor wretch's fellow secutor, Hypolitus, has to perform this last office, prior to encountering in his turn another retiarius, who is seen waiting in the distance.

GLAIRIN; *Baregin*; an azotised matter found in the water of hot sulphureous springs. It has been compared to albumen and gelatin, but its composition differs considerably from these bodies. It consists of,—

Carbon	45·20
Hydrogen	6·95
Nitrogen	5·60
Ash	40·70
Oxygen	1·55
	100·00

GLANDERS, or *Farcy*, is a name given by veterinary surgeons to a disease affecting horses and other cattle. It appears in the form of a suppurative disease of the mucous membrane of the nose and of a pustular eruption. The former is sometimes called glanders and the latter farcy, but the two often occur together, and the pus discharged by the one will produce the other. In 1821, Mr. Muscroft drew attention to the fact that this disease could be communicated from the horse to the human system. In the same year cases occurred in Germany, and since then it has been demonstrated by a large number of cases that this disease often spreads from the horse to man. When it attacks man it is characterised by vascular injection of the nasal mucous membrane, on which chancre-like sores are formed, extending to the frontal sinus and neighbouring mucous surfaces, from which a profuse and offensive discharge flows. At the same time a tubercular or pustular eruption appears upon the skin, followed by suppurating bloody or gangrenous ulceration in various parts. These symptoms may be either *acute* or *chronic*. In the acute cases a primary fever is followed by the local disease. In chronic cases the local affection alone presents itself. The acute disease is ushered in by rigors, pains in the back and limbs. These symptoms are followed by phlegmonous tumours in various parts of the body, which are accompanied with pain and tenderness, and terminate in abscesses or boils. At the same time a discharge takes place from the nostrils of a matter more or less purulent, viscid, and mixed with blood. The eyelids frequently become tumefied, and discharge a thick viscid matter like that from the nose. About the twelfth day of the disease an eruption breaks out on the face, trunk, and limbs. It is preceded and accompanied by profuse and fetid sweats. The eruption is scattered, and resembles, according to circumstances, the vesicles of cow-pox, or the pustules of small-pox or ecthyma. These are sometimes accompanied with large vesicles (bullæ), which become black, and discharging leave gangrenous sores. At first the pulse is full and quick; but it becomes rapid, small, irregular, and intermittent. The tongue is at first loaded with white fur, which afterwards becomes brown or black. Diarrhœa and tympanitis often come on in the course of the disease. This disease is generally fatal from the seventeenth to the twenty-first day. In the chronic cases the febrile symptoms are not so prominent. The local symptoms are much the same, but they progress more slowly. The abscesses are attended with a large amount of subcutaneous inflammation. A twelvemonth has been known to elapse in such cases as these before a patient has recovered or died.

There is no doubt that these symptoms are the result of a poison introduced into the system of man from the horse. In all cases contact with glandered horses has been ascertained to have taken place before the breaking out of the disease. Matter has been taken from the ulcers and membranes in men, and horses have been inoculated, and the disease has been produced. The disease has also been produced by compelling animals to swallow the poisoned matter in their food. There can, therefore, be no doubt that the poison can be absorbed both from mucous and cutaneous surfaces. This being ascertained, it becomes more than ever necessary to prevent contact with glandered horses. Such horses have been known to give the disease to persons riding behind them or passing near them by snorting the matter from their nostrils into the air. All glandered horses ought to be destroyed. In Germany the conviction of the danger of this disease is so strong, that all horses proved to have come in contact with glandered horses are ordered to be destroyed. Not only can this disease be communicated from horse to horse, and from the horse to man, but cases have occurred in which those attending glandered individuals have become affected. The poison of glanders soon manifests itself. Mr. Turner inoculated two young donkeys, and in one the maxillary glands became tender on the second day, and the discharge took place from the nose on the third day, whilst in the second the glands became swollen on the third day, and the discharge took place on the sixth. Cases have been recorded in which the incubation of the poison must have taken at least three months. In the human being the poison has remained latent from two to eight days after exposure.

This disease in its acute form is very fatal. Of fifteen cases recorded by Rayer only one recovered. Of the treatment, therefore, little can be said as a matter of experience. The general symptoms in the latter stages are those of low malignant fever, and a stimulant plan of treatment is indicated. Cases have been bled and cupped, and the blood was buffed, but there is no reason to believe that the bleeding did any good. In the chronic forms of the disease recovery is more frequent. The symptoms indicate the necessity of a generous diet.

We add the following remarks by Mr. Finlay Dun, V.S., in the 14th vol. of the 'English Agricultural Society's Journal,' pp. 128, 129:—

"From their weak and unsound constitution, horses of a scrofulous diathesis are unusually prone to *glanders* and *farcy*—two forms of a disease peculiar (at least as an original disease) to the equine species. As has been already remarked, it is characterised by a specific unhealthy inflammation, identical in all important characters with the syphilitic inflammation in man. From the dire and loathsome nature of glanders, and the terror in which it is held, animals affected by it are never used for breeding, so that we have little opportunity of judging of its hereditary nature. There is no evidence (so far as I know) which proves it to be directly hereditary, but there is no doubt that the progeny of a glanderous horse would exhibit an unusually strong tendency to the disease. Though I am not aware of any facts proving glanders to be congenital, yet I think there is every probability that such is the case; for it is notorious that syphilis, the analogous disease in the human subject, is congenital, and often appears at birth in the children of women affected by that disease. Its ordinary predisposing causes are, many of them, hereditary: it is very prone to attack animals of a weak or vitiated constitution. It is emphatically *the* disease which cuts off all horses that have had their vital energies reduced below the healthy standard, either by inherent or acquired causes. Glanders is also sometimes caused by inoculation; is frequently produced in healthy subjects by mismanagement, as by insufficient food, want of shelter, and overwork; and often supervenes on bad attacks of influenza, strangles, diabetes, and other diseases which debilitate the system, or impair the integrity of any of its more important parts. These causes appear to possess the power of engendering in the constitution of the horse a peculiar poison, which, as it reproduces itself, and spreads to all parts of the body, gives rise to the characteristic symptoms of glanders, causing, sooner or later, a breaking up of the system, and a fatal prostration of the vital powers. This poison produces in the blood abnormal changes, which vitiate that fluid, and unfit it for healthy nutrition. From the irritant action of the morbid fluids passing through them, the lymphatic glands and vessels become inflamed, and lymph is deposited. This, however, being of an unhealthy nature, soon runs on to softening, which extends to the skin overlying the part, and ulcerating farcy-buds are formed. On the surface of the more vascular mucous membranes effusions of tubercular matter are also poured out; these take on an unhealthy inflammation, and degenerate into chancrous ulcers, which may generally be seen on the mucous membrane of the nostrils in most bad cases of glanders."

GLASS MANUFACTURE. Glass, one of the most beautiful of manufactured products, is a transparent, solid, and hard substance, exceedingly brittle while cold; but by the application of a high degree of heat it is rendered so flexible and tenacious that it may with the utmost facility be moulded into any form. It is so ductile while heated, that it may be spun into filaments of the greatest conceivable fineness; and these when cold are exceedingly pliant and elastic.

The time at which glass was invented is very uncertain. The popular opinion upon this subject refers the discovery to accident. It is said (Plin. 'Nat. Hist.' lib. xxxvi., c. 26) "that some mariners, who had a cargo of *nitrum* (salt, or, as some have supposed, soda) on board, having landed on the banks of the river Belus, a small stream at the base of Mount Carmel in Palestine, and finding no stones to rest their pots on, placed under them some masses of nitrum, which, being fused by the heat with the sand of the river, produced a liquid and transparent stream: such was the origin of glass." The ancient Egyptians were certainly acquainted with the art of glass-making. This subject is very fully discussed in a memoir by M. Boudet, in the 'Description de l'Egypt,' vol. ix., Antiq. Mémoires. The earthenware beads found in some mummy cases have an external coat of glass, coloured with a metallic oxide: and among the ruins of Thebes pieces of blue glass have been discovered. Sir Gardner Wilkinson adduces three distinct proofs that the art of glass-working was known in Egypt before the exodus of the children of Israel from that land, more than 3500 years ago. The manufacture of glass was long carried on at Alexandria, from which city the Romans were supplied with that material; but before the time of Pliny it had been introduced into Italy, France, and Spain (xxxvi., c. 26). Glass utensils have been found among the ruins of Herculaneum.

The application of glass to the glazing of windows is of comparatively modern introduction, at least in northern and western Europe. In the year 674 artists were brought to England from abroad to glaze the church windows at Weremouth in Durham; but even in the year 1567 this mode of excluding cold from dwellings was confined to large establishments, and by no means universal even in them. An entry then made in the minutes of a survey of Alnwick Castle, the residence of the Duke of Northumberland, informs us that the glass casements were taken down during the absence of the family, to preserve them from accident. A century after that time the use of window-glass was so small in Scotland that only the upper rooms in the royal palaces were furnished with it, the lower part having wooden shutters to admit or exclude the air. It may be presumed that this window-glass was of home-make. The earliest manufacture of flint-glass in England was begun in 1557; and the progress made in perfecting it was so slow, that it was not until near the close of the 17th century that this country was independent of foreigners for the supply of the common article of drinking-glasses. In 1673 some plate-glass was made at Lambeth, in works supported by the Duke of Buckingham, but which were soon abandoned. It was exactly one century later that the first establishment of magnitude for the production of plate-glass was formed in this country, under the title of "The Governor and Company of British Cast Plate-glass Manufacturers." The members of this company subscribed an ample capital, and works upon a large scale were erected at Ravenhead, near Prescot in Lancashire, which have been in constant and successful operation from that time to the present day.

There are several distinct kinds of glass, which differ from each other in regard to some of the ingredients of which they are made, and in the processes of manufacture. The names *crown, flint, cut, window, sheet, broad, spread, blown, cast, plate*, &c., glass, are not very well chosen; but whatever be the names, the principal ingredients employed are silex or flint, and an alkali. The differences in the various kinds result from the description of alkali employed, and from the addition of certain accessary materials, usually metallic oxides. The form in which silex is now generally used in this country for glass-making is that of sea-sand, and care is required to select those kinds which are free from foreign matters and impurities. The port of Lynn in Norfolk, and Alum Bay in the Isle of Wight, have long furnished the greater part of the silex used in our glass-houses. Flint-glass derives its name from the practice in former times of using flints calcined and ground in the manner now employed for making porcelain; but this has long been discontinued. Of late there has been some apprehension of a scarcity of sand suitable to the manufacture; and a good idea may be formed as to the importance attached to the purity of this chief ingredient from the fact that sand has been imported for the purpose from New South Wales. The alkali employed for making fine flint-glass is pearl-ash, purified by solution and subsidence, in which process impurities to the extent of one-third of the weight are removed. Coarser alkaline substances are used for making inferior kinds of glass: the impurities even assist towards fusing the silex; but such alkalies all contain iron in some degree, and it is to the presence of this metal that the green colour of common glass is owing. Barilla and kelp were formerly the chief sources of the soda employed; but in recent years the carbonate and sulphate of this alkali have been obtained from common salt; either one alone, or the two combined, being chosen for different kinds of glass.

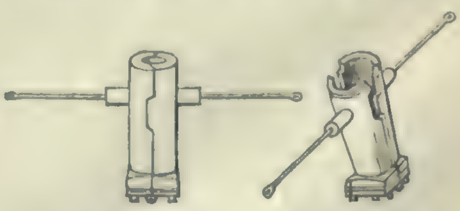
We shall now treat succinctly of the processes by which the principal kinds of glass are produced.

Flint Glass. This, known in other countries under the name of crystal, is the most generally useful, the most brilliant, and the heaviest description of glass. This last quality it owes to the large quantity of oxide of lead which it contains, and which is used sometimes in the form of minium, but more frequently in that of litharge. The metallic oxide acts as a flux, and promotes the fusion of the other materials at a comparatively low temperature. The greater density which it imparts gives to the glass a greater power of refracting the rays of light; and it is this quality which renders flint-glass of so much importance for optical purposes. Nitre in a small proportion is used for the destruction of any carbonaceous matter in the other ingredients; the oxygen which it gives out in the furnace further serves to maintain at their highest degree of oxygenation the metallic oxides that are present. Black oxide of manganese in minute proportion is also used to remove any foul colour that might otherwise remain through the impurity of the alkali used; its cleansing property occasioned this oxide to be known formerly under the name of glass-soap. Any undue proportion of manganese would impart a purple hue to the mass; and if any considerable quantity be used that colour will be deepened almost to black. When through inadvertence the glass has been made purple, the colour will be almost instantly discharged by thrusting a piece of wood into the melted mass. The cause of these changes is as follows:—The purple colour given by oxide of manganese arises from its being in a high state of oxygenation; the wood when thrust into the heated mass becomes speedily carbonised, and the carbon, combining with the superfluous oxygen, is driven off in the form of carbonic acid gas; if by the addition of nitre the quantity of oxygen is again increased, it will combine with the manganese, and restore the purple colour. It will be seen from these circumstances how much skill and experience are necessary for the due mixture of ingredients so as to produce glass of the best quality. The manufacturers of flint-glass are generally unwilling to disclose the precise proportions in which they employ the requisite ingredients; and it is probable that each has a favourite recipe of his own. One kind consists of 120 parts fine clean white sand, 40 well-purified pearl ash, 35 litharge or minium, 13 nitre, and a small (undefined) quantity of the black oxide of manganese. The French chemists recommend a much larger proportion of oxide of lead, but this is found to make the glass inconveniently soft. Where less metallic oxide is used, more nitre is required as a flux, and *vice versâ.*

The ingredients, in whatever proportions selected, must all be intimately mixed before they are put into the crucibles or pots, which are previously placed in the furnace. These pots are very carefully made of Stourbridge clay; they are about a yard in height, with only one arch-shaped opening at the side, and each will contain 16 cwt. of glass. As the bulk decreases by fusion, fresh portions of the ingredients are added until the pots are full of melted glass. A very strong and long-continued heat is necessary, not only for the perfect fusion and amalgamation of the materials, but also for the discharge of the impurities which they contain. The chief of these, known under the name of sandivir, or glass-gall, consists of salts existing in the alkali which have but small affinity for silex, and from their specific levity rise in the form of a white porous scum to the top of the crucible, whence it must be removed before it is volatilised by the excessive heat of the furnace. This glass-gall is used as a powerful flux by refiners of metals. When the whole of the impurities have been thus thrown off by the action of heat and are removed, and the glass, or *metal*, as it is called, appears colourless and translucent, the vitrification is known to be complete. The temperature of the furnace is then lowered by preventing the access of air until the glass loses a part of its fluidity, and assumes that pasty character which is the most convenient for the workmen; it being sufficiently consistent to be tenacious, but soft enough to yield to the slightest pressure without cracking or losing its tenuity. The material is usually brought to a perfect state of vitrification in about forty-eight hours from the first application of heat.

Melting-pots for Flint-glass.

There is perhaps no process of manufacture which more excites the surprise and admiration of a stranger than that of fashioning flint-glass into all the various objects of convenience and ornament for which it is employed. To see a substance, proverbially brittle, blown with the human breath, pulled, twisted, cut, and then joined again with the greatest facility, never fails to strike with astonishment those who are unaccustomed to the sight. The tools with which all these operations are performed are of the most inartificial description, and do not appear to have received any improvement from the earliest records of the manufacture. Most articles in flint-glass, such as drinking glasses, cruets, decanters, phials, &c., are made by the combined processes of blowing, manipulation, and casting, in varying degrees. A square perfumery bottle may be selected as an example of one kind. The workman takes a long iron tube, and collects a little of the melted glass on one end of it, by thrusting the tube through the open door of the furnace into the mouth of the melting-pot; this pasty glass is rolled into a cylindrical form on an iron plate, and is pinched at one place to form a neck. The glass is then thrust into a brass or iron mould, and the workman blows through the other end of the tube; the mould gives an external shape to the glass, while the current of breath hollows the interior. All this is done in less than half a minute. The mould, which consists of two halves hinged together, is opened; the glass is taken out; it is detached from the tube by a touch with a piece of cold iron; it is taken up on the end of a heated rod by another workman; and by means of a few simple tools the neck and mouth of the bottle are finished. A claret-jug may be taken as an example of another large class of flint-glass manufactures. The workman collects a considerable quantity of melted glass on the end of his iron tube, which is raised to elongate it, rolls it into a cylin-


Moulds for casting Flint-glass bottles.

drical shape, and blows through at the other end of the tube. Another workman then takes it; and by a combined process of blowing, rotating, and manipulation with small tools, the mass of glass gradually assumes the form of a jug, without being cast or pressed into any mould. A small quantity of glass is added and speedily fashioned into a foot for the jug, and another similarly for the handle. All these operations are effected with surprising quickness and precision. The glass is in such a medium state between solid and liquid, that while, on the one hand, it would drop from the tube if not kept rotating, it is, on the other, susceptible of being pulled, stretched, cut, pressed, and worked in various ways. The workman has nothing but his hand and eye to guide him in giving accuracy of shape to the article manufactured. The facility with which an additional piece attaches itself to and becomes part of the larger mass, enables the workman to supply all such appendages as the stems and feet of wine-glasses, the handles and lips of jugs, &c.

Blowing for Flint-glass.

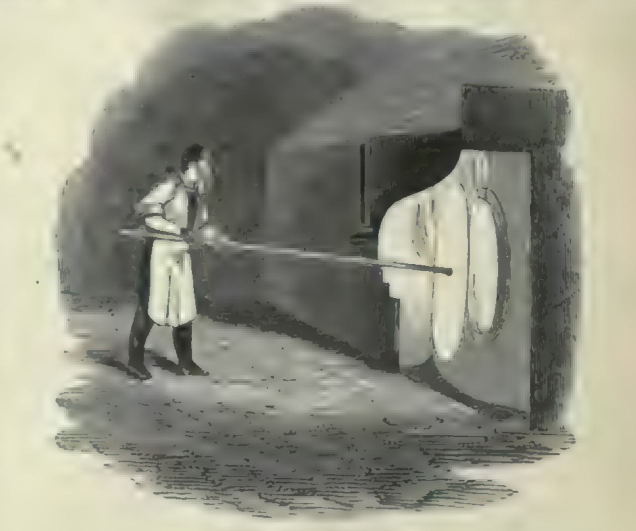
Flint-glass working.

Flint-glass is used for a large variety of purposes, and many adjustments of the manufacturing processes are found necessary. *Thermometer* and *barometer tubes* are made by an operation which depends on the remarkable ductility of glass. A workman collects a quantity of glass on the end of a tube; rolls it on an iron plate into a cylindrical form; blows into it to form a cavity within; and attaches the other end to a heated rod. Two men—the one holding the tube and the other the rod—then walk backwards, stretching out the tube of glass to a length of 40 or 50 feet. One of the most remarkable circumstances connected with this operation is, that the hollow within the glass retains exactly the same shape, although the mass may be extended from a few inches to 50 feet in length; and the workman can thus obtain either cylindrical or flattish tubes, as may be required. The tubes are broken into smaller lengths for use. In making *glass beads*, a very fine and narrow tube of glass is taken, and one end is placed in the flame of a lamp while the workman blows in at the other; he expands the heated end into a small hollow sphere by the action of his breath, and then breaks it off. So rapidly is this done, that one workman can produce five or six thousand in a day. Some of these beads, made of coloured glass, are used for necklaces; some, carefully treated afterwards, become *dolls' eyes;* while others, made of a slightly bluish-white glass, become *artificial pearls*, by being coated on the inside with pearl-essence, or essence d'Orient, a liquid prepared from the scales of the blay or bleak fish. The substance called *avanturine glass*, a Venetian product, is applied to the manufacture of trinkets and ornaments, and is named, on account of its resemblance to the natural crystal, avanturine. It is a yellowish-brown glass, inclosing fine thin yellow laminæ or scales of a brilliant metallic lustre. The manufacture is not well understood in England. Some think that the yellow laminæ are produced by melting scales of meta or mica with the glass; but it is deemed more probable that a salt of copper is mixed and melted with the glass, and that a powerful reducing agent decomposes this salt during the melting, and separates the copper in the state of thin metallic scales. *Venetian* and *Bohemian glass* are in general illustrations of the great diversities which can be produced in glass, by adding metallic oxides to produce colour, and by a peculiar treatment of the finishing processes; but the rationale and general character of the manufacture are sufficiently denoted by the description given above. The fanciful productions known by the names of *Venetian ball, Venetian filagree, Milléfiore glass, Mosaic glass, Smetz glass, Vitro di trino*, &c., are all specimens of flint-glass which have undergone peculiar treatment. *Optical glass* is mostly flint-glass, although the different refrangibility of other kinds leads to the combination of two or more in producing achromatic and aplanatic lenses. But, in truth, opticians care little about the name given to their glass; they have long been trying, and still are trying, to produce pieces large enough for telescopes of great diameter, and perfectly free from specks or blemishes; and if they succeed in this, it matters little whether the substance more nearly resembles flint, or plate, or crown glass. Mr. Cooper, a glass-manufacturer at Aberdeen, sent to the Scottish Society of Arts a few years ago two recipes for optical glass, which he had found advantageous. The first consisted of well-washed and sifted sand, 60 parts; oxide of lead, 60; purified carbonate of potash, 15; saltpetre, 3½; and broken flint-glass, 15 to 20. Another kind, heavier and of greater refrangibility, was composed of sand, 60 parts; oxide of lead, 63; carbonate of potash, 14; saltpetre, 3½; and broken flint-glass, 20. In 1854, M. de Peyrony submitted to the Académie des Sciences a proposal for a new mode of making optical glass for large lenses. In the usual way, the mass of glass having been brought to a state of fusion in the crucible, the material is simply stirred to make it homogeneous, and to drive out the included bubbles of air. But this double object is never completely attained; for the stirring itself occasions the formation of striæ, or waving lines, which necessitate the rejection of a large portion of the glass taken from the crucible, as being unfitted for the formation of lenses. Hence the difficulty of obtaining lenses of large diameter. M. de Peyrony proposed to give the crucible a motion of rotation around a vertical axis; the centrifugal force, he suggested, would unite the air-bubbles towards the centre of the mass, while the striæ made by the stirring would for the most part disappear; those that remain would probably assume a circular form, and would produce little inconvenience, provided the optician took care to make the axis of the mass coincide with that of the lens. The finest optical glass yet produced, perhaps, is a telescope-lens which was shown at the Paris Exhibition in 1855. M. Lelebours obtained the piece of glass from the glass-works at Choisy-le-Roi, and bestowed some months of labour upon it; it is 14 English inches in diameter. The French government bought it for what was considered by scientific men an inadequate price,—25,000 francs, or 1000*l.*; and it is now fitted into the finest telescope at the Paris Observatory. At the same Exhibition, Messrs. Chance, the glass-manufacturers of Birmingham, brought forward, not lenses, but discs of glass intended for lenses, of a size never before equalled. The discs were made, some of flint, and some of crown-glass; two of them were *twenty-nine inches in diameter* each. Sir David Brewster urged the British government to purchase these discs, and therewith to make "the greatest achromatic telescope that was ever contemplated by the most sanguine astronomer;" but without success.

Flint glass, for domestic and ornamental purposes, undergoes many processes after the moulding and shaping; such as annealing, cutting, engraving, gilding, &c. The process of *annealing*, intended to lessen the brittleness of the glass, is noticed under ANNEALING. The *cutting* consists in a grinding away of portions of the glass, to produce that peculiar effect which is familiar to every one in cut-glass. This is done by means of small wheels, made of cast-iron, wrought-iron, Yorkshire stone, willow-wood, and other substances. Each wheel is made to revolve very rapidly on a horizontal axis; the edge or periphery is that part by which the grinding is effected; and different shapes and thicknesses are prepared to suit different kinds of work. The workman holds the glass decanter or other article against the edge of a wheel, and modifies the position and pressure according to the effect desired to be produced. The iron wheels, wetted with sand and water, are used for grinding away the substance of the glass; the stone wheels, with clean water, for smoothing the scratched surfaces; and the wooden wheels, with rotten-stone and putty-powder, for polishing. The *engraving* of flint-glass consists in the production of devices on the surface more delicate than can be produced by the cutting wheel. It is effected by the use of very small discs, generally of copper, and moistened at the edges with emery and oil, and requires great taste and judgment for its due performance. The *parti-coloured* specimens of flint-glass are produced in a remarkable way. The working-tube of the maker is first dipped into a mass of colourless glass, and then into one of coloured; the glass is fashioned and annealed in the ordinary way, and then it is cut by the wheels; and according to the depth of the cutting or grinding, so does the workman penetrate, nearly or quite, through the coloured glass, giving rise to a beautiful play of tints. A different method of obtaining some such effect as this was devised by Mr. Johnson in 1853. It consists in laying a piece of glass on another piece of a different colour; softening and uniting them by the heat of an enamel-furnace; stamping a device on the upper surface by a die; and then grinding away most of the upper glass—by which the upper colour presents itself as a device set or incrusted in the lower. The *incrusted* glass, or *crystallo-ceramie*, invented by Mr. Pellatt, consists in forming a small medallion bas-relief, alto-relief, or other article, of a kind of clay which has the property of expanding and contracting by changes of temperature just in the same degree as flint-glass; this is imbedded in a mass of red-hot glass; and when cooled, annealed, fashioned, ground, and polished, the glass appears with the device in the middle of its substance; the clay, under these circumstances, presenting an appearance almost exactly like that of unburnished silver. The *gilding* of flint-glass is effected by processes not differing much from that of porcelain. [PORCELAIN MANUFACTURE.] Two or three patents have been taken out for *electro-gilding* on glass: but this process has not yet come extensively into use.

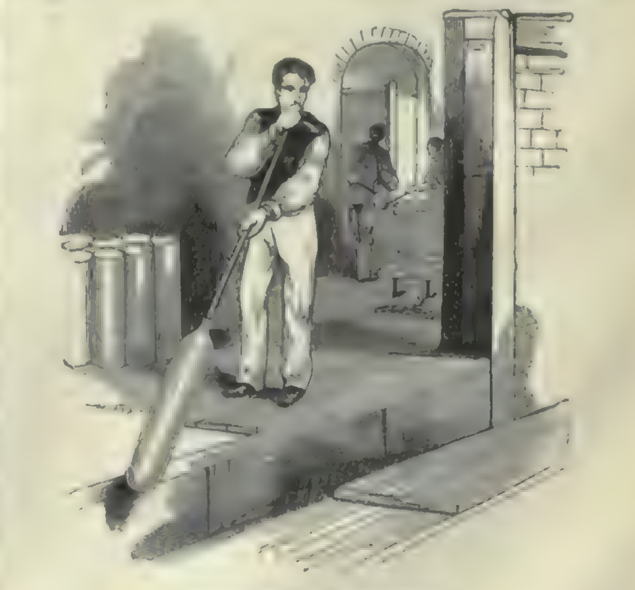
Artificial Gems.—Before passing to the consideration of other kinds of glass, we may say a few words concerning the art of making imitative gems and precious stones, which resemble flint-glass more than any other substance. A transparent, fusible, dense glass, called *paste* or *strass*, is the basis employed. To make good strass is the primary work to be done. There are many recipes for producing it. One, by Loysel, consists in using pure silica, 100 parts; red oxide of lead, 150; calcined potash, 30; calcined borax, 10; and arsenious acid, 10. This mixture produces a glass of great brilliancy, much power of refracting and dispersing light (on which the flashing lustre of gems, whether real or factitious, so much depends), and a specific gravity not far different from that of the diamond; it fuses at a moderate heat, and acquires additional brilliancy when kept heated for two or three days. Diamonds are imitated by this uncoloured strass; and other gems by mixing this strass with colouring agents. For every different factitious gem, there are numerous combinations known; but a few examples will suffice to illustrate the general character of all. *Amethyst:* strass, 100 parts; oxide of manganese, 8; and oxide of cobalt, 2. *Aquamarine:* strass, 4800 parts; glass of antimony, 30; and oxide of cobalt, 1½. *Avanturine:* strass, 500 parts; scales of iron, 100; and protoxide of copper, 50. *Beryl:* nearly the same as for aquamarine, of which beryl is only a variety. *Chrysolite:* strass, 7000 parts; and calcined sesquioxide of iron, 65. *Carnelian*, or *Cornelian*; strass, 7000 parts; glass of antimony, 3500; calcined peroxide of iron, 875; and binoxide of manganese, 75. *Emerald:* strass, 7000 parts; carbonate of copper, 65; and glass of antimony, 7. *Garnet:* strass, 1200 parts; glass of antimony, 580; purple of cassius, 3; and binoxide of manganese, 3. *Lapis lazuli:* strass, 7000 parts; calcined bones, 570; oxide of cobalt, 24; and oxide of manganese, 24. The golden veins in this beautiful stone are imitated by painting in the composition with a mixture of gold-powder, borax, and gum-water, and then applying a gentle heat till the borax fuses. *Opal:* strass, 960 parts; and calcined bones, 48. *Ruby:* strass, 45 parts; and binoxide of manganese, 1; or in another variety, 1 part of topaz paste, which has turned out too opaque, with 8 of strass, fused together for thirty hours, cooled, and fused again in small pieces before the blowpipe. *Sapphire:* strass, 3600 parts; oxide of cobalt, 50; and oxide of manganese, 11. *Topaz:* strass, 1050 parts; glass of antimony, 44; and purple of cassius, 1. *Turquoise:* blue strass, 20 parts; and calcined bones, 1. There is a peculiar mode of producing imitative rubies and emeralds by the use of a kind of alum-glass, subjected to a long and elaborate series of processes; and another, by M. Gaudin, for producing imitative sapphires by an equally elaborate treatment of alum and sulphate of potash. There are other modes of imitating gems; but we need not notice them here.

Crown Glass.—This is one of two varieties of *blown* glass. It is made without any admixture of metallic oxide, and is both specifically lighter and much harder than flint-glass. Many receipts have been given for the production of this kind of glass. At the great works of St. Gobain, in France, the mixture of ingredients is said to be: fine white sand, 100 parts; carbonate of lime, 12; carbonate of soda, calcined, 48; clippings of crown-glass, 100; with minute portions of manganese and cobalt to correct impurities, and to remove the colour which those impurities would impart; they are not therefore at all times necessary. In England the ingredients are mostly sand, alkali, and slaked lime, in the proportions of 200 of the first, 330 of the second, and 15 of lime, to which is added about half the weight of the three materials in broken crown-glass, called by the makers *cullet*. The perfect fusion and refining of these materials are usually accomplished in about forty hours. Crown-glass is made by blowing, in the form of circular plates of 54 to 70 inches diameter. A quantity of glass in the pasty state is collected upon the end of a hollow iron tube, five feet long, similar to the tube used for blowing flint-glass. The lump of glass is then converted, by blowing through the tube, into a hollow globe of the requisite substance. This globe is flattened at the side opposite to the tube by pressing it upon a hard plane surface; a solid rod of iron having a small quantity of melted glass at the end is applied, and adheres to the centre of the flattened side opposite to the tube; the tube is finally removed by wetting the glass near the point of union, leaving a small circular hole. To arrive at this stage the glass must have been several times re-heated, by placing it, when connected with the tube, within a small opening left for the purpose in the wall of the furnace. When transferred from the tube to the solid rod, called a *pontil*, it must be again heated in the same manner, and is then twirled round by the workman somewhat in the manner that a mop is twirled to drive off the moisture; with this twirling the softened material is continually driven off from the centre by the centrifugal force; the hole just mentioned expands, from a few inches to a foot or more in diameter, when suddenly, and in a most unaccountable manner, it flies open, and the whole substance is converted into a flat disc of circular form, and, except at the centre, where it is attached to the rod, of a uniform thickness. This *flashing* of the glass as it is called, is one of the most striking and surprising things in the whole manufacture. The centre parts are used for the commonest purposes, such as glazing outhouses and the poorer kinds of windows. As the shape of the tables or pieces of glass is circular, and as there is a bulb or bull's eye in the middle, it is impossible to obtain very large panes of crown-glass; and the differences of quality are so great and so uncertain, that the best are worth thrice as much per square foot as the worst. Nevertheless, there is always a brilliancy of surface upon crown-glass, which renders it valuable.



Flashing-out Crown-glass.

Sheet Glass.—This is another kind of blown-glass, which has become a very important article of manufacture in England within the last twenty years. Before that time, glass of a peculiar kind was imported, under the names of *broad*, *spread*, or *German sheet-glass;* but the sheet-glass of modern make is a French invention, and French workmen are largely employed in its manufacture, even in English establishments. It required six years, 1832 to 1838, for Messrs. Chance and other manufacturers to overcome the numerous difficulties which beset



Swinging and blowing Sheet-glass.

the manufacture; the difficulties were at length mastered; and among other results, "Crystal Palaces" were rendered possible. The process of making is from first to last very remarkable. The workman gathers up a quantity of the semi-molten glass on the end of a tube; rolls it on a concave block of wood to give it a cylindrical form; and then swings it completely round in a vertical circle, blowing through the tube repeatedly. A recess is formed in the floor of the building, to afford room for this swinging. Much bodily strength and great nicety are required in this operation. The hollow cylinder of glass stretches out by the swinging; but it must be so skilfully managed that the stretching may occur equally in every part, bringing the glass to one uniform thickness. The rotating before a fire, the blowing, and the swinging, are repeated until the proper thickness is attained, and the cylinder has attained the length of four, five, or even six feet. By a mode of causing the heated air within the cylinder to expand, the remote end becomes burst open; the tube is detached, and then the other end is expanded also. The cylinder, symmetrically shaped from end to end, is then laid down; and a diamond, fixed to the end of a long handle, is drawn along the interior, making a cut. The cylinder is placed in an oven, with the cut or fissure uppermost; it gradually opens, and flattens down to a sheet on a very smooth surface. The sheet is rubbed smoothly and evenly with a piece of charred wood, until as free as possible from any irregularities; after which it is annealed in another oven. Such sheets, when first made in England, seldom exceeded 36 by 20 inches; but the usual size now is 47 by 22 inches; and some rare examples have been produced as much as 77 inches in length, requiring no less than 38 lbs. of glass to be taken up on the end of the tube. Although sheet-glass, thus made, is less brilliant and more undulating than crown, its available size is so much larger, that its use has in recent years become very extensive. It was with sheet-glass that Messrs. Chance glazed the Crystal Palace in Hyde Park in 1851; the glass was made in sheets 49 inches by 30, from cylinders more than 4 feet long by nearly 10 inches in diameter: each sheet was cut up into three panes, 49 inches by 10; and of these there were 300,000 in number, measuring 1,000,000 square feet, and weighing 400 tons. The Crystal Palace at Sydenham has since been glazed with the same kind of glass. Messrs. Chance have recently succeeded in devising a process for grinding and polishing sheet-glass, by which it acquires nearly all the beauty of plate-glass with a much less weight; it is much prized by photographers. The German, or broad-glass, above adverted to, is made by the cylinder process, like sheet-glass; but it is clumsily-fashioned, the cylinder is cut open by scissors, and is made to spread out on a layer of sand in the oven, which does not admit of the production of so much smoothness and regularity. Until 1836 the cylinders of sheet-glass were cut open by a piece of red-hot iron; but now a diamond is employed. Such of the Bohemian and Venetian decorated glass as does not belong to the flint-glass kind, is made by the cylinder process.

Plate Glass.—This is both blown and cast. The first-named process was alone employed in England until the year 1773, when cast-plate began to be made. Larger pieces can be made by this than by any other method. The manufacture is difficult and costly. The ingredients are chosen with the greatest care, and every possible amount of skill is brought to bear on the manufacture. The ingredients used are sand of the purest and whitest quality, and soda produced by the decomposition of common salt and lime: manganese and oxide of cobalt being added for the purpose of discharging colour. Soda is preferred to potash or pearl-ash because the glass that is made with it flows better when in fusion, a quality of much importance where large quantities are employed for the production of the same piece. The lime acts as a flux, and is used in proportions varying from 1-24th to 1-16th of the whole materials employed. Besides these ingredients, it is necessary to use a large proportion of broken plate-glass or cullet. The following is one among many scales of ingredients: Lynn sand, well washed and dried, 720 parts; alkaline salt, containing 40 per cent. of soda, 450; lime, slaked and sifted, 80; nitre, 25; broken plate-glass, 425. It requires 40 hours' exposure to the full heat of the furnace to reduce the materials to the proper state of fusion and vitrification. When this is accomplished, the glass is transferred from the melting-pot, by means of copper ladles, to a large vessel called a *cuvette*, previously heated to a very high degree; when filled, it remains some hours in the furnace, to disperse the air that may have been introduced into the mass by the operation of ladling. When this effect has been produced, the cuvette is withdrawn from the furnace and taken to the casting-table, over the upper end of which it is raised and suspended by means of a crane. It is then thrown into an inclined position, by which the contents are allowed to flow out upon the table. The liquid glass is distributed by means of a roller over the whole surface of the table, bars of metal being placed at each side along its entire length, and across the bottom, in order to prevent the glass from running upon the floor. The casting of large plates of glass is one of the most beautiful processes in the arts: the large mass of melted glass, rendered in a high degree luminous by heat, exhibiting changing colours in the sheet after the roller has been passed over it. Previous to the casting, the table is placed with one end against the mouth of an annealing oven; and as soon as the plate is set, it is carefully slipped from the surface of the table to the floor of the annealing oven. When the oven has received as many plates as it will contain upon its floor, the door is closed and its crevices are stopped with mortar or clay, to insure the gradual cooling of the plates. The plates remain in the oven during a fortnight, after which the ovens are opened and their contents are withdrawn. The plates are then squared by means of a glazier's diamond, then ground and polished, and when intended for mirrors they are silvered. In order to their being ground they are imbedded in plaster of Paris. To commence the grinding, powdered flint is rubbed steadily and evenly over the surface by machinery worked by steam power, the two sides of the plate being ground in succession. Emery powder is then substituted for ground flint, coarse at first, but finer afterwards, as the rougher inequalities of the surfaces are removed. The polishing is also performed by steam-machinery. The plates are firmly fixed upon large tables, and the polishing instruments, which are of wood covered with many folds of woollen cloth, having carded wool between each fold, are passed to and fro over the surface. The polishing substance used is colcothal, and oxide of iron which remains in the retorts after the distillation of acid from sulphate of iron; the two surfaces are polished in succession.

The novelties introduced within the last few years in the plate-glass manufacture are as numerous as those which bear relation to sheet-glass; they have had the effect of cheapening the price and increasing the attainable size of the plates. Messrs. Swinburne, a leading firm in the glass trade, have it recorded in their books that their charge, in 1771, for a plate measuring 50 inches by 40, was 61*l*. 3*s*., whereas the price in 1856 was 4*l*. 4*s*. Some of the recent inventions relate to the form of the furnace and melting pots; some to the mode of tilting over the molten metal; some to the form and construction of the casting-table; and some to the mode of effecting the difficult operation of transferring the plate of glass from the table to the annealing oven. A few years ago Messrs. Hawks & Crawshay made for Messrs. Swinburne a casting-table of extraordinary size; it was a solid mass of iron 18 feet 4 inches long, 10 feet 10 inches wide, and 7½ inches thick, weighing 26 tons. A planing-machine was expressly constructed for planing and smoothing this iron surface. When the large plates of glass are annealed, the grinding and polishing begin: these processes, like all else, have been recently made the subjects of much inventive skill; but their details need not be noticed here. It is an interesting fact, connected with the history of the plate-glass manufacture, that the machinery constructed by James Watt for the Company in 1788 was still in existence, at the Ravenhead Works, and even in use, in 1858.

Bottle Glass.—This is the commonest kind manufactured, the alkali employed being the cheapest that can be procured, with the addition of a portion of lime to assist fusion. Considerable manufactures of bottle-glass are carried on at Newcastle-upon-Tyne, encouraged by the low price of the fuel (small coal) which is used in the furnaces. The ingredients are usually nothing more than lime and sea-sand, the latter article having been frequently wetted with sea-water, and allowed to dry, in order that the salt may be allowed to deposit itself in the sand; the soda contained in the salt is the only alkali, properly so called, that is used. Or, another mixture is, Tyne-sand, lime, and the refuse of the soap and alkali works. Bottle-glass is fashioned by blowing, much in the same manner as flint-glass, but with the addition of a moulding process. The description given in a former paragraph of making a flint-glass perfumery bottle will suffice to convey a notion of the mode of making wine and beer bottles, pickle and oil bottles, &c.; except that the latter are made with much less nicety. Four men can make about a hundred beer bottles in an hour. There is a greater weight of coarse green bottle-glass made in England every year than of all other kinds of glass combined.

Bottle-glass makin.

Stained or Coloured Glass.—Coloured glass is more easily produced than colourless, seeing that many niceties in the choice and management of ingredients are necessary to remove all tint from the glass. Nevertheless, to produce a particular colour is an art requiring much skill. As in the instances of enamels and artificial gems, the colours are mostly produced by adding metallic oxides or chlorides to the ingredients for the glass. Sometimes these are put into the melting-pot, to make the glass equally coloured throughout its substance; sometimes a coloured layer is applied to a colourless substratum. An example of this last-named kind has been noticed in a former paragraph, concerning cut flint-glass vessels exhibiting a gradation of tints; and flat panes of glass are produced in an analogous way, by collecting colourless glass on the end of a tube, dipping it into coloured glass, and then flashing it out into crown or sheet glass. So far as concerns the actual manufacture of coloured glass, the ingredients are nearly or quite the same, whether it be surface-colour or through-colour. What is called stained or, more properly, painted glass, however, is generally understood to be something in which the artist is more concerned than the manufacturer. It is a kind of enamel painting, or enamelling, and is effected in the way described in the next article. [GLASS PAINTING.]

Soluble or Water Glass.—We may here add a few words concerning soluble glass, which is at present exciting some attention. It is a chemical agent rather than a manufactured product; still, it is a vitreous substance as soon as it has solidified. About the year 1825, Dr. Johann Fuchs, of Nürnberg, commenced a course of experiments on the production of a liquid glass, produced by a fusion of silica with potash and soda. From time to time the subject came under public notice, but not with any definite result until recently. In the spring of 1859, at the request of the Prince Consort, Dr. Fuchs gave a summary of all that he had done, in a paper read before the Society of Arts. He made many varieties of the liquid glass, some with soda, some with potash, and some with both alkalies, combined in a particular way with crushed quartz or quartzose sand. He had been struck with the possible value of these silicates as a varnish, which, hardening into a glass, would preserve the surface of stone from decay; but his chief labours were towards the production of a new vehicle for fresco-painting. Meanwhile, Professor Kuhlmann, of Lille, had been engaged for many years in studying the action of the soluble silicates with the salts of lime; and in 1857 he made known the results of his method of proceeding, in producing a stone-protecting silicate. An English experimentalist, too, Mr. Ransome, was working towards the same end, but by a different path. He devised a mode of making artificial stone, by combining sandy or stony fragments with silicate of soda; and he also produced a vitreous varnish for the surface of stone, consisting of silicate of calcium instead of silicate of soda. Portions of the Louvre, of the Cathedral of Notre Dame at Paris, of the Houses of Parliament at Westminster, of the Baptist Chapel in Bloomsbury Street, of the Pavilion at Brighton, of the Custom House at Greenock, and of other buildings, have been coated with one or other of the different kinds of water-glass; but many controversies have thence arisen, and it remains yet to be proved how far this kind of vitreous coating will be permanently protective. The causes which bring about that decay of stone implied in all these experiments, are noticed under ATMOSPHERIC INFLUENCE. Another kind of soluble glass, intended to protect woodwork from the action of fire, is noticed under FIREPROOFING.

Glass Trade. The glass-trade in its fiscal and commercial relations, presents many instructive features. At an early period of its history in this country the glass manufacture became an object of taxation, and duties were imposed by the 6 and 7 William and Mary, which acted so injuriously, that in the second year after the act was passed one half of the duties was taken off, and in the following year the whole was repealed. In 1746, when the manufacture had taken firmer root, an excise duty was again imposed, at the rate of one penny per pound on the materials used for making crown, plate, and flint-glass, and of one farthing per pound on those used for making bottles. In 1778 these rates were increased 50 per cent. upon crown and bottle-glass, and were doubled on flint and plate glass. The rates were further advanced from time to time in common with the duties upon most other objects of taxation, and in 1806 stood as follows:—on plate and flint-glass, 49*s.* per cwt.; on crown and German sheet-glass, 36*s.* 9*d.* per cwt.; on broad glass, 12*s.* 3*d.*; and on common bottle-glass, 4*s.* 1*d.* per cwt. In 1813, those rates were doubled, and with the exception of a modification in 1819 in favour of plate-glass, then reduced to 3*l.* per cwt., were continued at that high rate until 1825. In that year a change was made in the mode of taking the duty on flint-glass, by charging it on the weight of the fluxed materials instead of on the articles when made, a regulation which did not affect the rate of charge. In 1830, the rate on bottles was reduced from 8*s.* 2*d.* to 7*s.* per cwt. The next alteration made in these duties occurred in 1835, when, in consequence of a recommendation contained in the thirteenth Report of the Commissioners of Excise Inquiry, the rate upon flint-glass was reduced two-thirds, leaving it at 2*d.* per pound; a measure rendered necessary by the encouragement given under the high duty to the illicit manufacture, which was carried on to such an extent as to oblige several regular manufacturers to relinquish the prosecution of their business. Such were the variations in the rate of duty; and the amount of revenue was equally fluctuating. In 1793, when taxation was comparatively low, the quantity of all kinds of glass made and retained for use in the kingdom was 407,203 cwt., and the amount of revenue obtained from it 177,408*l.* The average rate of duty was therefore 8*s.* 8½*d.* per cwt. upon the whole quantity. In 1834, the rate of duty had by progressive additions become fourfold what it was in 1793, the average being 35*s.* 7½*d.* per cwt. upon the aggregate quantity used; and although the population had in the mean time increased more than 60 per cent., the quantity of glass which was taken for use was only 374,351 cwt., or one-twelfth less than was so taken in 1793. If the quantity used in proportion to the population had continued the same, that quantity would in 1834 have amounted to 663,740 cwt., and a revenue equal to what was realised would have resulted from an average rate of 20*s.* instead of 35*s.* 7½*d.*

It was in 1845 that Sir Robert Peel took off the duty on glass. The effect was very marked—not so much on account of the actual duty thrown off, as on the removal of the exciseman from the glass-works, where he had hampered the manufacturer in all experimental attempts to improve the quality and cheapen the price of the manufactured article. Immediately before the removal of the duty, there were fourteen manufacturers of crown and sheet-glass in the United Kingdom; they became at once overwhelmed with work. The makers had neither buildings nor hands enough; they built new works, and hired workmen from abroad. The Frenchmen who worked at crown glass making could command 5*l.* a-week; while the makers of sheet glass earned 4*l.* to 8*l.* a-week. New companies were formed, and capital was thrown into the glass trade from various quarters. As in many similar cases, however, incompetence and recklessness did their work; the trade was weeded in the course of a few years, and the manufacture (of crown, sheet, and plate) is now in the hands of a small number of very large establishments. The excitement in England had a remarkable effect in Belgium. In the glass factories of that country, the workmen are engaged, not for a definite period, but for the "life of the furnace," as it is called, that is, as long as the furnace remains heated. The manufacturers, at the period in question, maintained the "life" of their furnaces as long as possible, to prevent their workmen from migrating to England, or from demanding higher wages. All these matters gradually found their proper level; and the glass trade is now extensive and steady in England, without being disturbed by convulsive changes.

The glass-trade, as far as concerns exports and imports, is not one of distinguished magnitude. The English factories are able to supply most of the home demand; while they are not well able to command a large export trade.

GLASS-PAINTING. The terms Painted Glass and Stained Glass are often used, and even by writers on glass-painting, as though they were synonymous. But there is a broad distinction between the two. Stained glass, is glass the substance of which has been stained or coloured in the process of manufacture. [GLASS MANUFACTURE.] Painted glass, is glass which, whether previously stained or colourless has had a design painted upon it with colours, usually metallic oxides, combined with a vitreous vehicle, or flux; and which colours, on being subjected to a powerful heat, have become permanently united with the surface of the glass. Windows formed wholly of one or other of these kinds of glass would be strictly either stained or painted glass windows, as the case might be. In mediæval examples, however, what are called painted glass windows are usually formed of a combination of stained and painted glass.

The art of making coloured glass was known to the Egyptians and Assyrians, and from them passed to the Greeks and Romans. That glass was used for windows by the Romans is certain from more than one passage in Latin authors, and from specimens of window-glass having been found both at Pompeii and Herculaneum. It is not known, however, though it is not improbable, that they glazed their windows with stained glass; but stained glass windows must have been in use at a comparatively early period in Byzantium. Byzantine-Greeks appear also to have been the first practitioners of painting on glass; and it is conjectured, with reason, that the practice of glazing with coloured glass in ornamental patterns, and the art of painting on glass, were both introduced into Western Europe from Byzantium, by way of Venice and Marseilles. The practice of glazing windows with stained glass arranged in patterns was imitated from the Byzantine-Greeks by the Saracenic races, and has been continued in the cities of the East down to the present time. The earliest reference to the use of stained glass windows in Europe appears to be in a passage of Prudentius (quoted by Labarte, 'Handbook of the Arts of the Middle Ages,' p. 66) about the beginning of the 5th century; but a more distinct mention of them is made in the following century. Painted glass windows are not spoken of for two or three centuries later.

The earliest existing examples of painted glass windows which Lasteyrie has been able to discover are in the abbey of Tegernsee, in Bavaria: they were presented to the abbey by Count Arnold in the year 999. Five other windows in the same abbey, painted by the monk Wernher, date between 1068–91. At Hildesheim there are also some which are attributed to one Bruno, and to the years 1029–39.

The earliest examples in France, the country in which the art of glass-painting was, during its most flourishing period, practised with the greatest success, belong to the 12th century: the oldest being a representation of the Funeral of the Virgin, in Angers Cathedral, of the first half of the century; the others are some medallion windows of a very remarkable character, placed in St. Denis by the Abbé Suger in the latter half of the century.

It was in the latter part of the 12th and the 13th centuries that the art made its greatest advance. Painted glass windows had now come to be regarded as essential in religious edifices of any pretension. It was the period in Gothic architecture corresponding to our Transition, and First Pointed or Early English styles. Thirteenth century painted glass windows abound in France, and are not unfrequent in Germany and our own country. They are of the kind known as mosaic and medallion windows; that is, the ground is made up of small pieces of stained glass of the shapes and colours requisite to form the patterns, while, as it were, imbedded in the midst of the mosaic ground, are medallions of a circular, trefoil, or quatrefoil shape, on which subjects from Scripture or the lives of the saints, are painted. The ground is usually of a rich ruby or sapphire hue; and a border of a playful and often an extremely graceful design incloses the whole. The figures are necessarily small, and, as in all the painting of that time, are drawn without much artistic skill. In these early examples, the drawing of the faces, hands, &c., is expressed by little more than a sort of outlining with a bistre or other dark colour. Shading, properly so called, and half-tints, are not attempted. The colour of the glass is preserved, for the most part, unbroken. But the subjects are treated with much quiet religious feeling, simplicity, and purity, while the colours are very rich and finely harmonised. Indeed, as decorative works, the windows of the 13th century are superior to those of any other period. The oldest English examples are in Canterbury and Salisbury cathedrals; but the finest are the magnificent five sister lancets (50 feet high) of York Minster, and the great rose window of Lincoln Cathedral, in which the central Majesty (or Christ in Glory) is surrounded by sixteen compartments containing the typical events of the life of Christ. The chief French examples—many of them of extraordinary grandeur and beauty—are in the cathedrals of Chartres, Bourges, Paris, Amiens, Soisson, Rouen, and Sens, and the Sainte Chapelle, Paris.

The painted glass of the 14th century (the epoch of our Second Pointed or Decorated Gothic style) was more vivid in colour, broader in style, and the painting better executed than in that of the preceding century; but it was less pure in conception, and less strictly subordinated to the general architectural effect. The mosaic ground is no longer universal; rich red or blue damasked stuffs or diapering being often substituted; and, instead of small Scriptural subjects in medallions, we find a prevalence of single figures under large heavy canopies, each occupying a single light (of the kind known as canopied windows, first introduced in the latter part of the 13th century); heraldic bearings are also now largely introduced; foliated ornaments and geometrical patterns abound, but the trefoil so common in the preceding style is seldom, if ever, seen in this; and, instead of the graceful arabesque border, we find frequently a running pattern of vine-leaves and grapes. Grisailles, or subjects painted in gray, now first came into vogue. One of the best examples of English work of this period is the east window of Bristol Cathedral: other characteristic examples occur at York Minster; Exeter Cathedral; the chapel of Merton College, Oxford; Tewkesbury Abbey Church; Norbury Church, Derbyshire; Lowick Church, Northamptonshire; and several other parish churches. Characteristic French examples occur in the cathedrals of Chartres, Evreux, Beauvais, Limoges, Lyon, Strasbourg, and Narbonne.

In the 15th century (the period of our Third Pointed or Perpendicular Gothic) a great change took place in glass-painting. The windows became still more individualised and less dependent on the architecture. The subjects occupied a larger space, and were treated more as pictures. Either each filled a distinct panel, or they were placed one above another without any ground to separate them. The mosaic pattern-work of stained glass was now altogether discarded, the whole being painted. The details are usually put in with much care, and very skilful manipulation is exhibited throughout. But the colour is poor, white glass is chiefly employed, and the general effect is cold and comparatively feeble. Some of the examples—the earlier ones especially—are, however, very elaborate and impressive: of this class is the magnificent east window of the choir of York Minster, which consists of no fewer than 116 compartments, each having a separate subject. This is undoubtedly the finest example of the style in England; and Lastruvie says it is one of the very finest in Europe. It was during this period that buildings and landscapes began to be freely introduced as backgrounds to the compositions. Canopied windows of this date have the canopies of a very ponderous character. Chichester and Winchester cathedrals; Henry VII.'s Chapel; Lincoln College Chapel, Oxford; Cirencester Church; Barton Church; Ludlow Church, Shropshire; and many other parish churches, possess excellent specimens of the painted glass of this period. Of French work, very fine examples are found in the cathedrals of Bourges, Evreux, Aix, Mans, &c. In Italy, where painting on glass had not hitherto been practised with much success, many works of great ability, though in a pictorial style, were now executed; and the names are preserved of many eminent artists who painted on glass, including several distinguished painters in oil and fresco. The artists of Florence particularly excelled as glass-painters.

By the end of the 15th century Gothic architecture was everywhere dead or dying; and the old mediæval spirit had departed also from the painting of glass. Palatial and domestic buildings were now adorned with painted glass windows as well as ecclesiastical edifices. The aim of glass painters was to rival the effects of oil paintings. Windows were indeed often mere imitations of oil pictures. The works of Raffaelle, Giulio Romano, Albert Durer, and other distinguished painters, were either copied or imitated. Subjects in which were a multitude of personages arranged with all the elaborate artifices of pictorial composition; landscapes with the effects of aerial, and buildings showing complex linear, perspective; foreshortened figures; the depth and obscurity of chiaroscuro,—all were attempted to be exhibited in painted windows, and the result was that what would have been impressive on a wall or canvas, looked on glass a shallow and feeble transparency. We have in this country some of the least unsatisfactory, because among the earliest and transitionary examples, in the splendid series of twenty-seven large windows of King's College Chapel, Cambridge (painted in 1527 and succeeding years). But in them is seen how entirely the true character of window painting was now lost sight of. The glass is treated as though it were canvas or panel, the picture being carried over the entire surface, without any regard being paid even to the massive stone mullions which occasionally cut the compositions in the most awkward manner. Another very superior example of its class is the great east window of St. Margaret's, Westminster. The celebrated windows of Fairford church also belong to this date; they are usually ascribed to Albert Durer, but no doubt inaccurately, though they are of German or Flemish execution. In France there are numerous fine examples of 16th century windows in the cathedrals of Bourges, Auxerre, Auch, Beauvais, Sens, Rheims, &c.; in St. Ouen, at Rouen; St. Gervais, Paris; and the Sainte Chapelle, Versailles. The cathedrals of Germany and the Netherlands afford many fine examples of this period, treated, as are those of Italy and France, quite in the spirit and much in the manner of the contemporaneous painting in oil. In many instances, indeed, the brilliant colours of glass were altogether neglected, the picture being a dingy monochrome. Several specimens, mostly of small size, of the German, Flemish, and Swiss painted glass of this period are in the South Kensington Museum.

From this time glass painting fell more and more into disrepute; though windows continued to be painted, and some glass painters, especially in France, acquired a certain celebrity. But the works produced up to some time in the present century continued to be copies of oil paintings, or of designs which could only be effective if painted in oil. What these were in our own country, even when artists of the highest standing were commissioned to prepare the designs, may be seen in the windows of New College Chapel, Oxford, designed by Sir Joshua Reynolds and painted by Jarvis; and of Trinity College Library, Cambridge, designed by Cipriani.

The renovation of the art was coincident with the revival of Gothic architecture. It has since been studied earnestly by archæologists, and pursued zealously by a numerous body of practitioners (aided by the experiments of many eminent chemists) in England, France, and Germany; and great success has been attained in the preparation of the glass, and in the various technical and manipulative processes. Hitherto, however, little original power has been exhibited in the designs; the object aimed at being mainly to produce faithful imitations of mediæval glass, the style selected being that of the 13th, 14th, or 15th century, according to the taste of the artist or the desire of the patron.

We have now to describe very briefly the method of painting on glass. Obviously this can only be done generally. The art can only be learnt from a practitioner, and of processes so strictly technical even a description would be out of place here. We shall at the end of the article give references to technical treatises, where the several processes are explained at length, and the various materials employed are fully described.

The first step is to prepare a careful cartoon the size of the painting. For a small work on a single plate of glass, the glass is laid on the cartoon, or on a tracing made from it, and the outline is accurately traced on the glass with black or brown, composed of a very fusible vitreous flux, coloured with a metallic oxide, and ground extremely fine in an essential oil (tar, spike, or lavender). The parts intended to be yellow, orange, or red are then coated, either on one or both sides, according to the tint required, with a mixture composed of an alloy of silver and antimony ground up with the red oxide which is obtained by subjecting sulphate of iron to a red heat. The glass is then exposed in a furnace or muffle to a red heat, or, as it is termed, fired, in which process the tracing colour is fused, and adheres permanently to the glass. The mixture of silver and antimony stains the glass, but does not melt, so that the oxide of iron, which is in the state of dry powder, may be brushed off, leaving the glass coloured, but as transparent as before. The other colours, composed of a very fusible glass coloured with metallic oxides, are then added, and the glass is again fired. In most cases the glass is fired between the application of each colour, as some colours require more heat than others. In the Munich works the glass is often fired seven times.

For convenience we have described the process as followed on a single sheet of glass; but in fact painted windows are usually composed of many pieces of glass fixed together in a leaden frame-work. For a painted window of this kind, the first step is to arrange carefully from the cartoon the several compartments into which the work shall be divided; and to determine the sizes and shapes of the pieces of glass, and the direction of the lead-work, so as not to interfere with, but if possible to support, the outlines of the figures and the lines of the composition, whilst sufficient firmness is preserved to the window itself. In a window of this kind, it will be remembered, the artist does not paint upon white glass merely, but as far as possible avails himself of glass already coloured (pot-metal as it is technically termed), only in his subsequent processes modifying by shadows or superficial tints the original colours. Each piece of glass is separately painted, shaded, or diapered, and then fired; the laying on of the colours and the firing being repeated as often as necessary. When the painting is completed the pieces are fixed in their leaden frame-work; this is supported by an arming of iron saddle-bars, and the whole is placed in its proper position in the building.

In glass painting the artist has many difficulties to surmount; and he can only hope to surmount them by a clear comprehension of the special requirements of his art, and the adoption of a specific style of treatment. His work is so placed usually that it can only be looked at from a distance. Being a window, his painting must not obscure but only modify the light. He may graduate his tints, but, when in position, not only do his more delicate gradations disappear, but even the half-tints are lost. In the countenances, refinements of expression are commonly valueless. The transparency of the medium at once refutes any close imitation of solidity in the objects. Hence the attempts to copy pictorial effects are always unsatisfactory. There is little chance of success except by unreservedly accepting the conventionalities of the art, and treating the window as a window, and not as a portion of wall-surface. The subject must be conventionally rendered, but not necessarily, therefore, archaically; there is no reason why the forms, costumes, and composition should not be as perfect as the artist can make them. In the colouring of the parts as well as of the whole, the most gem-like richness and brilliancy must be aimed after; and the window be rendered at once harmonious in itself, and in harmony with the other windows, as well as with the building of which it is a portion.

The following works may be consulted on the history of painting on glass: they will supply any further references the student may require. Lasteyrie, 'Histoire de la Peinture sur Verre d'apres des Monumens en France,' 2 vols. fol., Paris, 1838–56, a very splendid and erudite work, in which representations in chromo-lithography are given of the best French examples from the 12th to the 18th century. With it may be compared a 'History of Stained Glass from the earliest period of the art to the present time,' by W. Warrington, 1 vol. fol., 1848, which in a measure does for English glass painting what the work of M. Lasteyrie does for that of France; but unfortunately the series of chromo-lithographic designs (illustrating the changes of style from the 12th to the 16th century) are not copies of old windows, but of windows painted by the author himself in imitation of old ones: many ancient English as well as German and Flemish examples, however, are supplied in Weale's 'Divers Works of Early Masters in Christian Decoration,' 2 vols. folio., 1846–7. In Mr. J. D. Waring's 'Arts connected with Architecture, &c.,' fol. 1858, is given a series of examples executed in coloured lithography, by Mr. V. Brooks, of stained glass windows in Central Italy, from the 13th to the 15th century. Gessert, 'Geschichte der Glasmalerei in Deutschland, und Niederlanden, Frankreich, England, der Schweitz, Italien, und Spanien, von ihrem Ursprung bisauf die neueste Zeit,' 8vo., Stuttgart, 1839. On the theory and practice of the art, see 'An Enquiry into the Difference of Style observable in Ancient Glass Painting, especially in England, with Hints on Glass Painting, by an Amateur' (Chas. Winston), 2 vols. 8vo., Oxford, 1847; and 'An Introduction to the Study of Painted Glass,' by the same author, 8vo., Oxford, 1849; F. W. Oliphant, 'A Plea for Painted Glass,' 8vo., Oxford, 1855; Langloit, 'Essai sur la Peinture sur Verre;' P. Le Vieil, 'L'Art de la Peinture sur Verre et de Vitrie;' G. Bontemps, 'Peinture sur Verre au dixneuvieme siecle,' Par., 1845; E. O. Fromberg, 'Handbuch der Glasmalerei,' Leipz., 1851, translated into English under the title of 'An Essay on the Art of Painting on Glass,' 12mo., 1851; M. A. Gessert, 'Die Kunst auf Glas zu Malen,' translated into English under the title of 'A Rudimentary Treatise on the Art of Painting on Glass,' 12mo., 1851; Sir G. Wilkinson, 'On Colour,' pp. 23–55; and for the ancient Italian method of glass painting, 'Original Treatises dating from the 12th to 18th centuries on the Arts of Painting,' edited by Mrs. Merrifield, vol. i., chap. iv.

There is a kind of ornamental window-glass called *Matted Work*, in which the glass is covered with a very fusible composition, either white or tinted, previously reduced to an impalpable powder. This composition is then removed from certain parts of the glass, according to the required pattern, and, after firing, produces on the glass a dull ground with a bright pattern. The demand for ornamental glass having increased lately, several persons have attempted, some by stencilling, others by the application of machinery, to produce it at a cheap rate; and matted work can now be obtained at one-fourth of the price that would have been charged a few years since.

Another method of ornamenting glass, rather inappropriately termed *embossing*, consists of a bright figure on a dull ground. The parts intended to be dull are painted over with varnish; hydrofluoric acid is then poured on, which etches the glass to a certain depth. After the acid and varnish are washed off, the glass is ground by rubbing with another piece of flat glass and fine emery. This process removes the original surface of the glass, and produces the dull ground; and the design, having been sunken by the action of the acid, is untouched in the grinding process, and left bright.

GLAUBER'S SALT. [SODIUM, *Soda, sulphate of*.]

GLAUCINE, an alkaloid found in the leaves and stems of *Glaucium luteum*. It forms salts with the acids, and has a bitter acrid taste. It occurs in the form of pearly scales. *Glaucopicrine*, found in the same plant, differs from the above compound. The composition of both is doubtful.

GLAUCOMA (from γλαυκός, blue or bluish-gray), a disease of the eye, characterised by the pupil losing its naturally black colour, and presenting a clear or dull greenish hue. It was first described by Brisseau, partly from observations made in the post-mortem examination of the eyes of Bourdelot, physician to Louis XIV. It seems to depend essentially on disease of the choroid membrane and retina [EYE, in NAT. HIST. DIV.], generally combined with morbid alteration in the vitreous humour and hyaloid membrane, and in the lens and its capsule.

The symptoms by which it is indicated are pain in the head, over the brow, or across the forehead, weakness of sight, and a greenish colour of the pupil, most intense when one looks directly down into the bottom of the eye, where it seems almost as if there lay a piece of shining metal. The pupil is rather dilated, and the motions of the iris are slow. As the disease advances, the greenish colour becomes more marked, vision more and more indistinct, and at last, when it is entirely lost, the iris is quite motionless. Frequently the disease spreads to the lens, producing a glaucomatous cataract [CATARACT], and sometimes is accompanied with evident inflammation of the superficial parts of the globe.

The disease seems to consist in chronic inflammation of the deep-seated parts of the eye. Those of a gouty constitution, and especially those who have lived freely, and have passed the middle period of life, as well as persons of scrofulous constitution, or who are employed in very delicate work, are the most frequent subjects of it. It is also more frequent in some countries and classes than others. Scarpa never met with a case of fluidity of the vitreous humour during his long practice at Pavia; while in England such a condition is by no means rare in old persons. Benedict says that he found glaucoma very prevalent among the Jews in Breslau.

On examination of the eyes thus affected, the choroid membrane is found to have lost its black colour from the absence of pigmentum nigrum; it is become dull-brownish, and its vessels are often varicose; the vitreous humour is generally quite fluid, without a trace of hyaloid membrane, of a yellowish hue, or with small brownish-green or green spots scattered through it; the retina is often darker than natural, or marked with reddish or black points; the lens in part of a yellowish or deep amber colour, firm and transparent, sometimes pushed forward, so that the iris is in contact with the cornea.

The only diseases with which glaucoma can easily be confounded are cataract and gutta serena: it may be distinguished by its history; by the greenish colour of the pupil, which evidently arises from changes of structure in the parts behind it, and which is not visible when viewed laterally; by the defect of vision being disproportionate to the change of colour of the pupil; and by the sight being best in a strong light.

Early treatment is necessary, and it should be actively antiphlogistic; blood should be drawn from the temples, and purgatives, mercury, and abstemiousness be ordered. These, if they do not put a stop to the disease, will retard its progress, and relieve many of its symptoms, as the headache, &c. If, however, the pupil becomes quite green and the iris motionless, the case may be regarded as hopeless; for there are no means known by which the changes on which these symptoms depend can be removed.

(Beer, *Lehre von den Augenkrankheiten*; Lawrence, *On the Diseases of the Eye*; Mackenzie, *On the Diseases of the Eye*.)

GLAUCOMELANIC ACID ($C_{12}H_2O_6$, HO?), an acid said to be formed when an alkaline solution of ellagic acid is exposed to the air.

GLAUCOPICRINE. [GLAUCINE.]

GLAZING. This name is given to several different processes in the manufacturing arts, each of which calls for a brief notice.

1. *Window Glazing.*—This is the art of fixing glass in the frames of windows, &c. Putty, with which the glass is usually fixed, consists of whiting and linseed oil. As to the mode of cutting the glass, see DIAMOND. The defective state of most skylights, hothouse roofs, &c., shows that the art of glazing them is very imperfectly understood by those who practise it. When a skylight is glazed in the ordinary manner, the laps or horizontal joinings fill with water by capillary attraction whenever it rains, and the wind drives the water into the house. This process goes on as long as the shower lasts. Sometimes vegetable fibres hang down from the laps, and, acting as siphons, draw off the water taken up by them, which then falls into the house, and by its dropping injures tender plants, &c. The retained water also expands in freezing, and fractures the glass.

The following remarks are the result of long practical experience and careful observation. The edges of the glass which are to form the laps should not be cut straight, but circular; this will add to the beauty of the work, and cause the water to run down the centre of the openings, and not act so much on the bars. The cutting of glass in this manner for domes and other ornamental roofs, where the spaces between the bars are not parallel, was formerly difficult to execute, and expensive on account of the waste of glass; but by a contrivance invented a few years ago, this may now be accomplished with ease, expedition, and economy. The laps should be less than a quarter of an inch wide, and wholly filled with a cement composed of putty with a good proportion of lamp-black, which will remain tougher and be more waterproof than white-lead, carbon being much less soluble than carbonate of lead. Some glaziers cement the laps at the time when they are glazed, and leave a space in the centre to allow, as they say, the water that forms inside to run out; but the spaces thus left are large enough to allow of the formation of sufficient ice to break the glass. Cementing is of little use if done when the work is first glazed. After the glazier has left his work as finished, the glass, which is very elastic, springs up enough to leave the included cement loose and inefficient. The elasticity of the glass may be taken advantage of after the side putty is set firm. If the cement is then pressed into the laps and care is taken that they are dry, the action opens the laps, and the re-action of the glass closes them, and holds the cement fast and firm.

The largest glazing operations ever carried on in this country were probably those at the two Crystal Palaces, Hyde Park and Sydenham. At the former there were 17 acres of window-glass in the roof alone, besides that in the windows. The panes or squares mostly measured 49 inches by 10; and they were fitted into no less than 200 *miles* of sash-bars.

2. *Metal-glazing.*—This has nothing to do with the fixing of glass, or the application of a vitreous coating; it is a particular mode of polishing metals, especially cutlery. The *glazers*, so largely employed at Sheffield, are wooden wheels covered with leather, and charged with fine emery, waxed to deaden the cutting action to a proper degree. The larger kinds are built up piecemeal, with six or more sectors having the grain placed radially. Mahogany, walnut, oak, crab-tree, and birch, are the chief kinds of wood employed, mahogany being the best; and the wheels are turned into proper form before the edges are dressed. The emery is applied in the state of a fine powder, moistened with water. Other varieties of polishing wheel are used, nearly like glazers. Buff-wheels are covered with leather in some cases half an inch in thickness, taken from a bull's neck; or sometimes old military belts are used as a substitute. They are coated with *coarse buff* of sand and water for polishing steel; and with *fine buff* of rotten-stone and oil for brass, Britannia metal, horn, ivory, tortoiseshell, &c. Leather glazers are covered with harder leather than buff-wheels; it is usually thick sole-leather; the emery is attached to the surface by means of glue; and such glazers are used for polishing various kinds of steel goods. Leather polishers are wooden wheels covered with soft thin leather, and supplied with crocus, rubbed on dry; they are used likewise for steel goods. The various leather-edged glazers used by cutlers vary from four to twenty inches in diameter, and from a quarter of an inch to four inches in width at the edge. At Sheffield, leather is tanned expressly for many of these kinds of glazers, with a view to the extraction of every particle of grease. Lapidaries employ wooden glazers in smoothing soft and rounded stones; these glazers are made of beech, birch, or mahogany; and emery is applied to their edges in a powdered form, moistened with water. In what way the emery admits of many different modes of treatment is explained under EMERY; while the relation which the process of metal-glazing bears to other operations of Sheffield goods is shown under CUTLERY.

3. *Fictile Glazing.*—In EARTHENWARE and PORCELAIN, descriptions are given of the circumstances under which a vitreous glaze is rendered necessary on the surfaces of articles in baked ware; and on the modes in which the heat of an oven fixes this coating when applied. We shall here speak only of the glaze itself. Most glazes are white, but they can be deepened to any tint by the addition of the same kinds of colouring ingredients as are usually added to enamels. Nearly all glazes contain lead, except when to be applied to articles which would be injured by that metal. A glaze without lead, for chemical vessels and some other articles, is made of Lynn sand 47 parts, potash 38, slaked lime 9, and nitre 4; these are pulverised, brought to the state of a paste or frit by heat, and again pulverised. One among many kinds of glaze for common earthenware consists of white lead 59 parts, ground flints 36, Cornish stone 16, and ground flint-glass 5. A glaze for porcelain consists of felspar 27 parts, borax 18, fine sand 4, nitre 3, soda 3, and Cornish clay 3; the whole being mixed, ground, heated to a frit, again pulverised, and finally treated with a small addition of calcined borax. A glaze for painted stone-ware consists of felspar 26, soda 6, nitre 2, and borax 1; when these have been fritted together, they are added to a mixture of red lead 50, white lead 40, and ground flint 12. All these various kinds of glaze, when prepared, and about to be used, are ground to powder, and mixed with water to a smooth creamy liquid, into which the ware is dipped. In some few cases, the ware is dipped into water, and the glaze sprinkled on it in the form of dry powder. The heat of an oven finishes the operation.

4. There are other processes of glazing in the arts, which consist in little more than the application of a varnish or glaze of white of egg or some similar substance.

GLAZING. [EARTHENWARE; PORCELAIN.]

GLEANING. The practice of gleaning in corn-fields what the reapers of the harvest leave behind is vulgarly supposed to be a legal custom which the "owner or occupier of the field has no right to prohibit, and that the poor who enter a field for this purpose are not guilty of trespass." The act has, however, been decided to be illegal. In the first case in which the question was raised the defendant pleaded that he being a poor, necessitous, and indigent person, entered the plaintiff's close to glean; and in the second the defendant's plea was the same, with the addition that he was an inhabitant legally settled within the parish. The Court held that the claim had no foundation in law, and that, "it was a practice incompatible with the exclusive enjoyment of property, and was productive of vagrancy and many mischievous consequences." (1 H. Bl. Rep.' 51.)

GLEBE LAND, the portion of land belonging to a parish church over and above the tithes. If there be both a rector and a vicar, the glebe land in the occupation of either does not pay tithes, though if in the occupation of a tenant it does. The representatives of a deceased incumbent are entitled to the corn sown by him upon the glebe. Various statutes have from time to time been passed to facilitate the exchange of glebe lands, which are often scattered in small parcels in different parts of the parish. It is doubtful whether a parson may open mines upon his glebe, though he may work any that are open.

GLEE, in music, a vocal composition in three or more parts, any instrumental addition to which is absolutely illegitimate, because pernicious in effect; except in the case of unsteady performers, when the use of a piano-forte, gently touched, is advisable, as an evil of less magnitude than false intonation and broken time. The word is derived from the Anglo-Saxon ᵹlıᵹᵹ (*gligg*), which signifies *music* generally; hence the term *Serious Glee* may possibly not be so gross a solecism as is commonly supposed; though it must also be admitted that the word usually implied cheerfulness; and we are told by Warton that *gleeman* (ᵹlıᵹman), answers to the Latin *joculator*.

The glee is of English growth, though the madrigal seems to have been its parent. The term is confined exclusively to this country, and does not appear to have been employed till towards the latter part of the 17th century; but Dowland, Ford, Ravenscroft, and others, published nearly a hundred years before compositions having all the character of that which subsequently took the name of *Glee*, frequently calling them part-songs, and occasionally applying the term madrigal to them, notwithstanding their deficiency in what chiefly characterises the latter.

Glees are called *serious* or *cheerful*, according to the sentiment of the poetry. The most distinguished authors of this delightful species of music are—(mentioning only those who now are personally beyond the influence of praise or censure)—Arne, Baildon, Callcott, Cooke, Danby, Hayes, Mornington, Nares, Paxton, Spofforth, Stafford Smith, Stevens, and Webbe.

GLIADIN, *Glutin*, a peculiar azotised vegetable matter which exists in small quantity with the gluten of wheat, and to which the adhesive properties of the latter are owing. It may be separated by boiling alcohol, together with a thick fluid oil which is separable by ether. Gliadin is adhesive, insoluble in water, when dried it is hard and translucent like horn; it dissolves in acetic acid and solution of potash. In composition it scarcely differs perceptibly from gluten. It contains in 100 parts,—

Carbon	53·27
Hydrogen	7·17
Nitrogen	15·94
Oxygen and sulphur	23·62
	100·00

GLOBE, the common term for a sphere, but most frequently used to signify the earth itself, or the sphere on which a representation of the earth or heavens is drawn.

GLOBE MAKING. This special department of industry is one in which few hands are employed, for the demand is limited; but it requires considerable tact and experience. Most English globes are hollow pasteboard balls. A wooden or iron mould is first formed, with wires projecting at opposite sides to represent the earth's poles. Several layers of long strips of paper are then pasted one over another on the mould, the *undermost* not being pasted to the wood or iron, but kept down close upon it. These layers may be from four or five to a dozen in number. When dry, this pasteboard envelope is cut in the line of the (future) equator, and is separated from the mould or ball in two hemispheres. These are fastened by nails to the two ends of a piece of wood exactly equal in length to the diameter of the globe; and the edges of the hemispheres are glued together, so as to form a pasteboard sphere. Two wires, projecting from the two ends of the piece of wood, penetrate the pasteboard, and form the termini of the axis of the globe. The pasteboard is then coated, six or more times over, with a composition of whiting, glue, and oil, until a considerable substance has been laid on; each layer being dried before the next is applied. At this stage of the manufacture any irregularity in the rotation of the globe on its axis is remedied, by increasing the thickness or the weight in particular parts. The plaster surface, when made quite smooth, is then marked with lines to represent the circles of latitude and longitude; this is done by women, who use a beam-compass for the purpose. Meanwhile the engraver has been at work, to produce the geographical delineation which is to cover the globe; the whole surface is divided into lens-shaped pieces, like the gores of a balloon, seeing that it is only by such means that the surface can be easily covered without overlapping or vacuities. Two circular pieces cover the arctic and antarctic regions; and the gores extend only to a meeting point within these pieces. The printing is effected on thin but very tough paper. In globes of moderate size, each gore usually represents 30 degrees of longitude, and 133 degrees of latitude. The pieces are pasted, and laid on with great care—the lines marked on the plaster being taken as guides. Much skill is needed to effect the necessary junction of the edges without overlapping. The globe is then coloured, to mark the divisions of land and water, &c., and is next coated with several layers of strong varnish. There is thus a hollow globe of pasteboard, coated with plaster, covered with printed paper, and finished with water-colour and varnish. The graduated meridian rings are made of brass or of iron. The "poling of the meridian," or adjustment to make the globe revolve truly, follows; and then comes the cabinet work of fixing the globe to its frame or stand—an engraved annulus or ring of paper being prepared to cover the representative horizon.

The same principle of manufacture is followed, whether the globes sell at six shillings or fifty guineas a pair. Small German globes are now imported, however, as low as sixpence each; and it is probable that some more rapid method is adopted for their production. Some of the English globes are as much as 36 inches in diameter. Some, of large size, contain not only the ordinary delineation, but also show the geological structure of the earth, atmospheric currents, trade winds, monsoons, ocean currents, isothermal lines, and trade routes. A celestial globe has been made as much as 72 inches in diameter, but with the delineations written or painted instead of engraved. Slate globes are made, for school use, with only the lines of latitude and longitude marked. Some globes are made with the land portions shown in *relief;* these require a process of embossing by stamping. Embossed globes of this kind are made to show approximately the irregularities on the moon's surface. Mr. Adams makes globes of gutta percha, which can be taken to pieces for convenient packing, or for instruction in putting them together again. He has also invented a globe in which the terrestrial and celestial spheres are superimposed one on the other—but to the disadvantage of both. Ziebermayer of Vienna makes globes in which a small terrestrial sphere is inclosed in a glass sphere marked with the constellations, &c., with mechanism for showing the places of the sun and moon among the stars. Globes have sometimes been made of tissue paper, inflated by air to a diameter of ten or twelve feet, and suspended by a string from the ceiling of a school-room or lecture-room. Betts's smaller paper globes are so constructed as to fold up conveniently into a very small space when not in use. Messrs. Goodyear manufacture globes of inflated india-rubber, or silk coated with india-rubber solution. The globes which have been made large enough for persons to enter withinside—such as Guérin's Georama, 30 feet in diameter, and Wyld's Great Globe, 60 feet in diameter—are examples of building rather than of globe-making.

The engraved paper surface of one of Addison's 36 inch globes was made use of by Professor Rigaud, of Cambridge, for determining the relative quantities of land and water on the earth's surface. The paper was selected with especial care; the printing was effected with as little ink as possible; the drying and cutting out were well attended to; and the pieces were weighed in a very delicate balance. Halley and Long had done the same thing with smaller globes long before; but Rigaud's process was in every way more trustworthy. On all globes the Arctic and Antarctic positions are necessarily left very vague; and the professor could only make guess-work of those regions. The result of a very laborious examination was, that if the earth's surface be divided into 1000 equal parts, 266 of these are dry land, and 734 water. The 266 are thus distributed:—Europe and the adjacent islands 16½, Asia 89, Africa 59½, America 85½, Australasian group 15½. In another mode of grouping, the northern hemisphere comprises 197 land and 303 water: the southern hemisphere 69 land and 431 water.

GLOBE OF COMPRESSION, a name given by Belidor to overcharged mines, that is, producing anything over a two lined crater. [MINE.] Such mines have been used by the besiegers of a fortress to destroy the galleries of the counter-mines, and blow the wall of the counterscarp into the ditch. They were first employed by the king of Prussia, in 1762, at the siege of Schweidnitz.

GLOBULAR PROJECTION. We believe this term has been applied to more than one species of map, but particularly to the projection proposed by Lahire, in which the eye is supposed to be distant from the globe represented in whole or part by one half of the chord of an arc of ninety degrees. This projection gives but a small distortion, compared with that of the stereographic projection; it is however very rarely employed, on account of the projections of most of the great circles being ellipses.

GLOBULAR SAILING. [GREAT CIRCLE SAILING.]

GLOBULIN, an albuminous substance contained in the blood-globules, united with *hematin*, the colouring-matter of blood. It is contained, also, in the crystalline humour of the eye. Its aqueous solution coagulates at a higher temperature than that of albumen. It possesses a slightly alkaline re-action, and in other respects greatly resembles albumen. It is composed of,—

Carbon	54·5
Hydrogen	6·9
Nitrogen	16·5
Sulphur	·3
Oxygen	21·8
	100·0

GLOVE (from the Anglo-Saxon *glof*), a cover for the hand. Casaubon asserts, with reference to a passage in Athenæus (xii. 2), that the ancient Greeks and Romans knew of no such covering for the hands; though he shows that they were in use among the Romans in the time of Pliny the younger. The Persians used gloves in cold weather, a circumstance charged against them as a proof of their luxurious habits. Xenophon, 'Cyrop.,' viii. 8, 17.

In England the etymology of the word shows the early use of gloves. With kings, nobles, and prelates in the Middle Ages they were a costly article of dress, and richly decorated, being sometimes, particularly those of bishops, adorned with precious stones.

While the spirit of chivalry lasted, the glove of a lady, worn in the helmet as a favour, was a very honourable token; and much of the wearer's success was supposed to be derived from the virtue of the lady. The practice of wearing a glove as a favour is mentioned by Hall in his 'Chronicle,' in the reign of Henry IV., and frequently among our old dramatic writers. Nares's 'Glossary,' in voce.

At what is called a maiden assize, or when there are no prisoners to be tried, it has from time immemorial been the custom for the high sheriff to present the judges with white gloves. Formerly on an application for the reversal of an outlawry, the defendant was obliged to appear personally in court and present gloves to the judges. Gloves are not worn in the presence of the sovereign.

In former times it appears to have been a general custom during fairs to hang out a glove from the town hall or some other conspicuous place, and it is said that whilst the glove remained suspended, all who visited the fair were privileged from arrest. The taking down of the glove was the signal that the fair was closed. (See instances and authorities collected in 'Notes and Queries,' vols. vii. and viii.)

At the sale of the Earl of Arran's goods, in the month of April, 1759, the gloves given by Henry VIII. to Sir Anthony Denny were sold for 38*l.* 17*s.*; those given by James I. to his son Edward Denny, for 22*l.* 4*s.*; and the mittens given by Queen Elizabeth to Sir Edward Denny's lady, for 25*l.* 4*s.* Gough 'Sepulchr. Mon., i. 185, says, "These may be supposed some of the oldest gloves extant."

To throw the glove by way of challenge to duel is mentioned in Matthew Paris's History, under the year 1245. He calls it *mos Francorum.* Throwing down a glove as a challenge by the royal champion was a part of the coronation ceremony as late as the coronation of George IV.

GLOVE MANUFACTURE. Gloves are made at the present day of a great variety of substances,—kid, lambskin, buck, doe, dog-skin, and other kinds of leather; together with silk, flax, cotton, and wool, and mixtures of two or more of these. Some are known by names which do not denote the materials used, such as Limerick, Berlin, Woodstock, Kendal, Yeovil, &c. "Habits," or habit gloves, are ladies' short gloves; the name being derived from the gloves formerly worn by ladies on horseback, at a time when long gloves were worn with walking dress.

The following observations on the characteristics of the chief kinds of gloves, in a manufacturing point of view, are mostly condensed from Mr. Perkins's useful little volume on the subject. Kid is valuable for gloves in proportion to its elasticity; when it is both elastic and close in texture, it is employed for the best "town made" gloves, which are equal in quality to the best French. Most of the so-called kid gloves sold at a low price are made of lambskin; the leather is always thicker and heavier than real kid. It is only the very best English kid gloves which are equal to the French; and as the latter have a good name in the market, there is much deception practised. Three-fourths of the real kid gloves sold in England as "French," are made in England, of kid skins obtained from France, Italy, and Ireland. Limerick gloves are a peculiar kind of kid, and are mostly worn in Ireland. Buckskin is a close-grained and very strong leather for gloves; it has a little elasticity, and bears cleaning well. Sheepskin gloves are generally white, and are used for the army. Tan gloves are cheap and serviceable articles of a tan colour, for gardening, riding, and driving; the top is finished by a cuff formed by reversing the face of the leather. Beaver is an inappropriate name for the commonest kinds of leather gloves, mostly dyed drab. Woodstock is a kind of superior beaver, in which much attention is paid to cutting and sewing. Doeskin is a more substantial, durable, and soft leather than that employed for beaver or Woodstock gloves. Silk gloves are classed in quality partly according to the weight of silk, and partly to the neatness of the sewing. About the time of the Great Exhibition, silk gloves were introduced, cut upon the same principle as kid gloves; and these have since been much sought after, as presenting a better and neater fit than the general kinds of textile gloves. Berlin gloves were originally imported from Berlin; then from some parts of Switzerland: but now they are largely made in England, where they are considered to be very superior to the cotton gloves which they superseded. Thread gloves are made of flax, hemp, and cotton, according to their price and quality.

So far as concerns the English glovers as a body, it appears that in London they were incorporated by Charles I. in 1638, although they had long before formed a guild among themselves. The guild, as in nearly all cases, sought to create or maintain a monopoly; and the charter enabled them to do this. Deer and sheepskin gloves were the kinds chiefly made in London at that time; but after the introduction of kid gloves into England, the London makers took up that branch, and have ever since conducted it more successfully than the glovers of other parts of England. Worcester has produced gloves for nearly three hundred years; first of the beaver, or oil-leather kind, and then of the tanned or alumed leather, of which kid is an example. At Woodstock gloves have been made ever since the time of Queen Elizabeth. Ludlow, Leominster, and Yeovil, are other towns in which leather gloves are made. The introduction of knitted or looped fabrics for gloves, similar in texture to hosiery, has had the effect of removing much of the glove manufacture to the counties of Nottingham, Leicester, and Derby, where such fabrics are mostly made; this novelty, and the larger importation of French gloves on the lowering of the duty, have had the effect of reducing the manufacture of leather gloves in most of the above-named towns.

The economy of the glove manufacture is generally somewhat as follows. Taking Worcester as an example, the master-manufacturers live in the town, while the glove-sewers live in all the villages for many miles round about. These sewers are mostly the wives and daughters of country people, who eke out a scanty subsistence by this means. The leather employed mostly undergoes its preparatory preparation at some of the tanneries in Bermondsey, but it is finished at Worcester. The dressed skins are cut out in workshops, either by the shears and guide-pieces, or by cutting machines of quicker action. All the necessary thumb-pieces, finger-side pieces, &c., are cut out in proportionate number; and enough pieces for a dozen pairs are made up into a parcel. The sewers either send to the warehouse and take away the parcels of pieces, or agents of the manufacturer make a tour among the neighbouring villages at stated intervals, bring glove-pieces to be made up, take away the gloves which have been made since the last visit, and pay for the labour bestowed upon them: there may be branch establishments at a few of the villages, each of which is the centre of a district of glove-sewers. The sewers use a clasp or clam, which is held between the feet and knees, and which clasps the leather or leathers while being sewn; in some cases the sewer is aided by a kind of brass comb or notched plate, for ensuring regularity in the stitches. Some of the women and girls confine their attention to sewing the different pieces together; some work the ornamental stitching at the back of the glove, while others finish the top. It may here be remarked, however, that sewing-machines are gradually finding their way into the glove-trade; but it is only a portion of the work which can be done by their aid.

About ten years ago it was estimated that 46,000 persons were employed at glove making in England, producing gloves valued at about one million sterling annually. During the years 1856–7–8, French gloves were imported to the number of about 4,000,000 pairs annually.

GLUCIC ACID ($C_{24}H_{18}O_{18}$, 3HO); *Kalisaccharic acid.* Glucose, or grape sugar, forms, with bases, definite combinations, termed glucosides. Within a short time after the formation of such compounds their solutions are decomposable by a current of carbonic acid with separation of unaltered sugar; but even at ordinary temperatures they soon begin to undergo change; the liquid, at first powerfully alkaline, becomes neutral, and a substance of strongly acid character remains in combination with the base. To this substance is given the name *glucic acid.* On the addition of subacetate of lead to the neutral solution, sub-glucate of lead is precipitated, and this, on being decomposed by sulphuretted hydrogen, furnishes glucic acid.

Glucic acid is colourless and uncrystallisable, in appearance it somewhat resembles tannin, is very soluble in water and alcohol, has an acid taste, and combines with some bases to form neutral and acid salts. These salts are difficult to obtain in a crystallised condition; but the general formula of the neutral ones appears to be $C_{24}H_{15}M_3O_{18}$ + Aq.

When solution of glucic acid is boiled, it absorbs oxygen, becomes brown, and a new uncrystallisable acid is formed. To the latter Mulder gives the name *apoglucic* acid.

GLUCINA. [GLUCINUM.]

GLUCINUM (Gl.), the metallic base of an earth or oxide (*glucina*) discovered by Vauquelin in 1798, in the beryl, or aqua marina, and afterwards in the emerald. Before the discovery of potassium, glucina and all other earths were considered as simple substances. Glucinum was first obtained from glucina in 1827 by Wöhler, who procured it by decomposing the chloride of glucinum. Obtained in this mode, glucinum is a fine powder of a deep gray colour, which is very difficult of fusion. But, according to more recent experiments, it is, after fusion, a white malleable metal of sp. gr. 2·1, fusing at a lower heat than silver. It does not burn when heated in air or oxygen, neither does it decompose the vapour of water at a red heat.

Dilute acids and solution of potash dissolve glucinum, with the evolution of hydrogen gas, and its consequent conversion into glucina.

Glucina (Gl_2O_3), the only known oxide of the metal, is obtained from the minerals which contain it, by fusing with carbonate of potash, and treatment with acids and with carbonate of ammonia, which dissolves the glucina, and leaves the alumina unacted upon; the carbonate of ammonia being expelled by heat, pure glucina remains.

The properties of glucina are, that it is a light white powder, which has neither smell nor taste, infusible, insoluble in water and solution of ammonia, but soluble in potash and soda; its specific gravity is about 3.

Glucinum combines readily also with chlorine, iodine, bromine, sulphur, &c.

Chloride of glucinum (Gl_2Cl_3) is obtained by cautiously evaporating a solution of glucina in hydrochloric acid. The residue is colourless, sweet, very fusible and volatile, and sublimes readily in white brilliant needles; it deliquesces in the air, and dissolves largely in water with the extrication of heat. When procured by evaporation, it is a gummy mass, which contains water, and when heated in the air is decomposed into hydrochloric acid and glucina.

Sulphide of glucinum is formed by heating the metal in the vapour of sulphur. Much heat is given out, and a gray sulphide of the metal is obtained, which is soluble in water and decomposed by acids, with the evolution of hydrosulphuric acid.

The salts which glucina forms with acids are not important; we shall therefore mention only their general properties. They are all colourless, except the chromate, which is yellow; the taste is sweet, and hence the name of the earth, and slightly astringent. With potash and soda they give a white precipitate of hydrate of glucina, which an excess re-dissolves; but ammonia in excess does not re-dissolve the hydrate. The carbonate of ammonia in excess re-dissolves the precipitated carbonate, and so also do, slightly, the carbonates of potash and soda. Neither ferrocyanide of potassium nor tincture of galls gives any precipitate. With fluoride of potassium there is produced a double salt, which crystallises in small scales, provided the solutions are hot, and the admixture is continued till the solutions begin to be turbid.

GLUCOSE. [SUGAR.]

GLUCOSIDES. A number of vegetable substances which yield sugar under the influence of various chemical agents are comprehended under this term. The following is a list of the best known glucosides:—

Phloridzin ($C_{42}H_{24}O_{20}$, 4Aq.), when boiled with weak acids, is decomposed into grape-sugar and a resinous matter named *phloretin*:—

$$\underbrace{C_{42}H_{24}O_{20}}_{\text{Phloridzin.}} + 4HO = \underbrace{C_{12}H_{14}O_{14}}_{\text{Grape sugar.}} + \underbrace{C_{30}H_{14}O_{10}}_{\text{Phloretin.}}$$

Quercitrin ($C_{36}H_{18}O_{20}$ + 2Aq.) is transformed into *quercetin* and grape-sugar when boiled with dilute sulphuric or hydrochloric acids:—

$$\underbrace{C_{36}H_{18}O_{20}}_{\text{Quercitrin.}} + 4HO = \underbrace{C_{12}H_{14}O_{14}}_{\text{Grape sugar.}} + \underbrace{C_{24}H_{8}O_{16}}_{\text{Quercetin.}}$$

Arbutin ($C_{32}H_{22}O_{19}$), under the influence of synaptase, yields grape-sugar and *arcturin*:—

$$\underbrace{C_{32}H_{22}O_{19}}_{\text{Arbutin.}} + 2HO = \underbrace{C_{20}H_{10}O_{7}}_{\text{Arcturin.}} + \underbrace{C_{12}H_{14}O_{14}}_{\text{Grape sugar.}}$$

Esculin ($C_{42}H_{24}O_{26}$), when digested with synaptase or boiled with dilute acids, yields *esculetin* and grape-sugar:—

$$\underbrace{C_{42}H_{24}O_{26}}_{\text{Esculin.}} + 10HO = \underbrace{C_{18}H_{6}O_{8}}_{\text{Esculetin.}} + 2(\underbrace{C_{12}H_{14}O_{14}}_{\text{Grape sugar.}})$$

Descriptions of these glucosides are given under their respective names.

GLUE. [GELATINE.]

GLUTEN is the name given to the viscid, sticky, and more or less elastic substance that remains when wheaten flour, inclosed in a bag, has been well kneaded under water. It is exclusively a vegetable product, is a characteristic ingredient of all the cereal grains, but is notably contained in wheat and rye.

Gluten plays an important part in the manufacture of bread, a portion of it inducing alteration of the starch and subsequent fermentation, while another portion, on account of its elastic property, admits of the expansion or *rising* of the dough, and by its adhesive property gives permanence to that expansion by preventing the expanding gas from escaping. [BREAD.]

As an article of food, gluten is a nutritive or flesh-forming material, containing about 16 per cent. of nitrogen; and as large quantities of it are produced in the manufacture of wheat-starch, it has, under various forms, been introduced as an alimentary substance. *Gluten bread,* given to diabetic patients, may be readily made. *Gluten biscuits,* also have been proposed; and a kind of maccaroni or vermicelli, similar to the Italian pastes, was sometime since introduced into commerce. *Semola* is, essentially, wheat-flour from which a large proportion of the starch has been washed, and the residue dried and granulated.

Gluten is not a single definite body, but contains four distinct principles,—glutin, vegetable fibrin, vegetable casein, and an oily matter. [FIBRIN; GLIADIN.] Gluten is soluble in cold acetic acid and weak alkaline solutions; from these liquids it is again precipitated on carefully neutralising. The mineral acids form compounds with it. In the dry state it forms a brown horny-looking mass, that may be preserved for any length of time; but in the moist condition it rapidly putrefies.

GLUTIN. [Gliadin.]

GLYCERAMINE. [Glycerin.]

GLYCERIC ACID ($C_6H_6O_8$). This body was first discovered by Debus, who obtained it by the oxidation of glycerin by means of nitric acid. One part of glycerin mixed with its volume of water is placed in an upright cylinder, and one part of strong nitric acid allowed to flow underneath the glycerin. The two layers gradually mix, and oxidation takes place with disengagement of gas. After the action is over, the product is evaporated in small quantities in the water bath, diluted with water, neutralised with chalk, and strong alcohol added, which precipitates the lime salts. These are then dissolved in warm water, filtered, and to the filtrate excess of milk of lime is added, which precipitates certain impurities. The liquid is again filtered, the free lime removed by carbonic acid, and the liquid evaporated to crystallisation.

The acid is obtained by precipitating the lime-salt with oxalic acid, and evaporating the filtrate in the water bath. In its state of greatest concentration it is a thick yellowish syrup, which dried at 284° Fahr. has the appearance of gum arabic. It readily attracts moisture. Its aqueous solution decomposes carbonates, coagulates milk, and dissolves iron and zinc with disengagement of gas. The salts of glyceric acid crystallise well; they have the general formula $C_6H_5MO_8$.

Glyceric acid can be considered as being derived from glycerin in the same manner as glycolic acid from glycol, or as acetic acid is derived from ordinary alcohol:—

$$\underbrace{\left.\begin{matrix}C_4H_5\\H\end{matrix}\right\}O_2}_{\text{Alcohol.}} \qquad \underbrace{\left.\begin{matrix}C_4H_4''\\H_2\end{matrix}\right\}O_4}_{\text{Glycol.}} \qquad \underbrace{\left.\begin{matrix}C_6H_5'''\\H_3\end{matrix}\right\}O_6}_{\text{Glycerin.}}$$

$$\underbrace{\left.\begin{matrix}C_4H_3O_2\\H\end{matrix}\right\}O_2}_{\text{Acetic acid.}} \qquad \underbrace{\left.\begin{matrix}(C_4H_2O_2)''\\H_2\end{matrix}\right\}O_4}_{\text{Glycolic acid.}} \qquad \underbrace{\left.\begin{matrix}(C_6H_3O_2)'''\\H_3\end{matrix}\right\}O_6}_{\text{Glyceric acid.}}$$

According to this view of its constitution, glyceric acid is tribasic. But the salts of glyceric acid, as far as they have been examined, are monobasic. In order to decide the question as to the basicity of glyceric acid, the ethers and the amides ought to be investigated; until this is done, the formula may be written $\left.\begin{matrix}(C_6H_3O_2''')\\H_3\end{matrix}\right\}O_6$ although it must be confessed that at present this view is nothing more than a probable hypothesis.

GLYCERIDES. [Glycerin.]

GLYCERIN ($C_6H_8O_6$), *Hydrated oxide of lipyl.* This substance was discovered by Scheele in 1779, who obtained it in the preparation of lead plaster. He named it, "sweet principle of oils," from its sweet taste. Subsequently, its properties were more accurately studied by Chevreul in his classical investigations on the chemical history of bodies of fatty origin, and by Pelouze. Recently Berthelot and De Luca have greatly extended our knowledge of this substance.

Most of the fats and oils of the animal and vegetable kingdoms have a constitution analogous to that of the compound ethers,—acetic ether, for example. When that substance is treated with alkalies it assimilates the elements of water, forming an alkaline acetate and alcohol. Oils and fats in like manner undergo by the same treatment a similar change. They assimilate the elements of water, glycerin is set free, and a salt of the acid, previously in combination with glycerin, is formed. On this decomposition the methods of preparing glycerin are based.

Glycerin may be prepared by saponifying oils with oxide of lead: equal parts of olive oil and of finely powdered litharge are mixed in a basin with water, the mixture heated to boiling for some time, and continually stirred, water being added to replace that which evaporates. Insoluble lead salts (in this case, the oleate and stearate of lead) are formed; warm water is then added, and the aqueous liquid decanted, filtered, and sulphuretted hydrogen passed through the filtrate, in order to precipitate a small quantity of oxide of lead, which dissolves. The filtered liquid is then evaporated in vacuo, or over the water bath.

Glycerin is also obtained as a by-product in the manufacture of stearin candles, in which case, the saponification is effected by means of lime.

But the simplest method, and that to which we owe the abundant and cheap supply of glycerin met with in commerce, is the one introduced by Wilson. It consists in treating the fats in a suitable distilling apparatus with superheated steam. The fats assimilate the elements of water, and are decomposed into their constituents—the fatty acids and glycerin. Both distil over, and form in the recipient two layers of liquid, of which the lower is tolerably pure aqueous glycerin. To purify it still further it may be again distilled with high pressure steam, concentrated in the water bath, and ultimately in vacuo over sulphuric acid.

Pure glycerin is a colourless, viscous, neutral, inodorous liquid, with a sweet taste, from whence it derives its name (γλυκός, sweet). It is uncrystallisable; at 40° Fahr. it becomes gummy, and almost solid. It is miscible with water and alcohol in all proportions, but is insoluble in ether. It attracts moisture from the air, and becomes more limpid. Concentrated as far as possible in vacuo over sulphuric acid, it has the sp. gr. 1·285 at 150° Fahr. It is difficultly volatile, and only begins to distil unchanged at 518° Fahr. When its aqueous solution is distilled some glycerin passes off with the vapour.

Pasteur has found that glycerin is contained in all fermented liquors, and more especially in wine. Its quantity amounts to 3 per cent. of the fermented sugar.

Decomposition of glycerin.—When glycerin is rapidly heated in a closed vessel above its boiling point, it is decomposed, with formation of inflammable gases, acetic acid, and acrolein. Derivatives of glycerin also, such as the natural oils and fats, by destructive distillation, yield acrolein, the characteristic odour of which readily indicates the presence of glycerin in any of these bodies.

Mixed with platinum black, and placed in oxygen, glycerin absorbs a large quantity of this gas, with the formation of inadequately investigated acid products, probably containing glyceric acid, which are ultimately oxidised to carbonic acid and water.

When an aqueous solution of glycerin is exposed in contact with yeast to a temperature of 68–85° Fahr. for several months, a large quantity of propionic acid is produced, together with some formic and acetic acids.

According to Berthelot, glycerin passes by fermentation into alcohol, when it is left for some time in contact with chalk and decaying cheese to a temperature of 85–105° Fahr.

When glycerin is gently heated with hydrate of potash or soda, it is converted into acetate and formiate, with liberation of hydrogen. Acrolein appears to be first formed, this then passes into acrylic acid, which in turn is resolved into acetic and formic acids.

In contact with anhydrous phosphoric acid, glycerin becomes strongly heated, and acrolein is disengaged; this is also the case when it is distilled with bisulphate of potash.

Strong nitric acid converts glycerin in a great measure into *glyceric acid*, $C_6H_6O_8$. By a mixture of strong nitric and sulphuric acids, it is converted into *nitro-glycerin* $C_6H_5O_3, 3NO_5$.

The oily nature of glycerin, its property of not solidifying, even when exposed to great cold, its permanency, its pleasant taste, its solvent powers, and the cheap rate at which it can be procured, will eventually secure for it an extensive use in pharmacy, arts, and manufactures. A few of its applications may be here mentioned.

It has been used to preserve articles of food, botanical and zoological preparations. When added to confectionary wares, preserved fruits, and chocolate, it serves to prevent them from becoming dry. It serves a similar purpose in the manufacture of tobacco and snuff. The water in gas-meters is liable to freeze in winter, and evaporate too rapidly in summer; the addition of glycerin prevents these evils. Glycerin is also used in the manufacture of copying ink, and in lubricating. It is also used, under a patent, in preparing paper for dry printing.

Glycerides, and constitution of glycerin.—The glycerides are the compound ethers of glycerin. To understand their nature the constitution of glycerin must be understood, and the two points can best be discussed together.

The natural fats and oils, as previously stated, have a constitution analogous to that of the compound ethers. This view of their composition was first propounded by Chevreul. Afterwards, Duffy, in an investigation of stearin, found that the quantity of stearine, which in saponifying forms one equivalent of stearic acid, only forms one-third of an equivalent of glycerin. Subsequently, Berthelot succeeded in artificially forming a large quantity of the natural fats, by directly combining the acids with glycerin, and it is on these researches, and on an interpretation of them proposed by Wurtz, that the prevailing views of their constitution are based. Berthelot found that the acids could be made to combine with glycerin in three different proportions, with elimination of the elements of water, and he characterised glycerin as a polyacid alcohol, that is, as an alcohol in which several equivalents of hydrogen are replaceable by acid radicals to form ethers. He considered glycerin as bearing to alcohol a somewhat similar relation to that which tribasic phosphoric acid bears to nitric acid.

Ordinary alcohol we may consider to be derived from the type of a double atom of water $\left.\begin{matrix}H\\H\end{matrix}\right\}O_2$ by the substitution of the monoatomic radical ethyl for an atom of hydrogen; and a compound ether is alcohol, in which another atom of hydrogen is replaced by an acid radical, such as acetyl. Thus:—

$$\underbrace{\left.\begin{matrix}H\\H\end{matrix}\right\}O_2}_{\text{Water.}} \qquad \underbrace{\left.\begin{matrix}C_4H_5\\H\end{matrix}\right\}O_2}_{\text{Alcohol.}} \qquad \underbrace{\left.\begin{matrix}C_4H_5\\C_4H_3O_2\end{matrix}\right\}O_2}_{\text{Acetic ether.}}$$

In like manner we may consider glycerin to be derived from the type of *three* double atoms of water by the substitution of the teratomic radical C_6H_5''' for three atoms of hydrogen. Thus:—

$$\underbrace{\left.\begin{matrix}H_3\\H_3\end{matrix}\right\}O_6}_{\text{3 atoms of water.}} \qquad \underbrace{\left.\begin{matrix}C_6H_5'''\\H_3\end{matrix}\right\}O_6}_{\text{Glycerin.}}$$

This view of the constitution of glycerin is supported by an experiment of Wurtz, in which he succeeded in obtaining glycerin artificially. By the action of terbromide of allyl, $C_6H_5'''Br_3$, on acetate of silver, a body is formed which has the composition and all the properties of triacetin. When this body is decomposed by baryta water, acetate of baryta and glycerin are formed. Terbromide of allyl is not a derivative of glycerin, it belongs to the allylic alcohol series. The following re-actions exhibit the change :—

$$\underbrace{\left.\begin{matrix}C_6H_5''' \\ Br_3\end{matrix}\right\}}_{\text{Terbromide of allyl.}} + \underbrace{3\left.\begin{matrix}C_4H_3O_2 \\ Ag\end{matrix}\right\}O_2}_{\text{Acetate of silver.}} = \underbrace{3AgBr}_{\text{Bromide of silver.}} + \underbrace{\left.\begin{matrix}C_6H_5''' \\ (C_4H_3O_2)_3\end{matrix}\right\}O_6}_{\text{Triacetin.}}$$

$$\underbrace{\left.\begin{matrix}C_6H_5''' \\ (C_4H_3O_2)_3\end{matrix}\right\}O_6}_{\text{Triacetin.}} + \underbrace{3BaO\,HO}_{\text{Hydrate of baryta.}} = \underbrace{\left.\begin{matrix}C_6H_5''' \\ H_3\end{matrix}\right\}O_6}_{\text{Glycerin.}} + \underbrace{3\left(\left.\begin{matrix}C_4H_3O_2 \\ Ba\end{matrix}\right\}O_2\right)}_{\text{Acetate of baryta.}}$$

In alcohol there is only one atom of hydrogen replaceable by a radical to form a compound ether. In glycerin there are three atoms capable of being replaced, and accordingly we may have three series of ethers, thus :—

$$\left.\begin{matrix}(C_6H_5)''' \\ R \\ H \\ H\end{matrix}\right\}O_6 \qquad \left.\begin{matrix}(C_6H_5)''' \\ R \\ R \\ H\end{matrix}\right\}O_6 \qquad \left.\begin{matrix}(C_6H_5)''' \\ R \\ R \\ R\end{matrix}\right\}O_6.$$

All these three classes are represented by compounds, some of which have been prepared directly from their constituents, and some exist already formed in nature. The glycerides which compose the natural fats are almost all normal neutral glycerides, that is, they contain 3 eq. of hydrogen replaced by 3 eq. of an acid radical, and the natural fats are almost all mixtures of several of these glycerides.

From the above view of the constitution of glycerin. it is obvious that a great number of glycerides may exist, according as 1, 2, or 3 eq. of hydrogen are replaced by 1, 2, or 3 of the same or different acid radicals. We may also have glycerides of the following composition :—

$$\left.\begin{matrix}(C_6H_5)''' \\ R'' \\ H\end{matrix}\right\}O_6 \qquad \left.\begin{matrix}(C_6H_5)''' \\ R'' \\ R\end{matrix}\right\}O_6 \qquad \left.\begin{matrix}(C_6H_5)''' \\ R'''\end{matrix}\right\}O_6$$

It is evident that glycerin may give rise to the formation of a great number of ethers, according as the atoms of hydrogen are replaced by different monoatomic radicals, or by a biatomic radical, or by a teratomic radical, where R'' and R''' are respectively biatomic and teratomic radicals.

The natural glycerides have been named by adding to an abbreviation of the name of the acid, the termination *in*, thus we have *stearin*, *olein*, &c. The artificial fats have been named in accordance with this principle, and the prefixes mono-, di-, and tri-, express respectively the proportions of the radical contained in them. Thus we have :—

$$\underbrace{\left.\begin{matrix}C_6H_5''' \\ (C_{36}H_{35}O_3) \\ H_2\end{matrix}\right\}O_6}_{\text{Monostearin.}} \qquad \underbrace{\left.\begin{matrix}C_6H_5''' \\ (C_{36}H_{35}O_3)^2 \\ H\end{matrix}\right\}O_6}_{\text{Distearin.}} \qquad \underbrace{\left.\begin{matrix}C_6H_5''' \\ (C_{36}H_{35}O_2)^3\end{matrix}\right\}O_6}_{\text{Tristearin.}}$$

Similarly we have :—

$$\underbrace{\left.\begin{matrix}C_6H_5''' \\ (C_4H_3O_2) \\ H_2\end{matrix}\right\}O_6}_{\text{Monoacetin.}} \qquad \underbrace{\left.\begin{matrix}C_6H_5''' \\ (C_4H_7O_2)^2 \\ H\end{matrix}\right\}O_6}_{\text{Diacetin.}} \qquad \underbrace{\left.\begin{matrix}C_6H_5''' \\ (C_4H_3O_2)^3\end{matrix}\right\}O_6}_{\text{Triacetin.}}$$

According to Berthelot, the artificial fats are formed by heating the hydrated acids along with glycerin in closed vessels for some time to a more or less elevated temperature. Many of them are formed even at the ordinary temperature. The glycerides containing 1 eq. of acid are mostly obtained by the continued heating of a mixture of hydrated acid with excess of glycerin to a temperature of 392° Fahr.

Of those containing 2 eq. of acid, some are obtained by continuously heating glycerin with excess of acid to a temperature of 392° Fahr. In some cases combination takes place at 212° Fahr.; in others the temperature requires to be raised to 527° Fahr.

The neutral compounds are obtained by heating the above compounds with excess of acid to a temperature of from 464° Fahr. to 500° Fahr.

In many cases the glycerides may be obtained by saturating a mixture of glycerin and the acid with hydrochloric acid, and heating to 212° Fahr.

The combination of glycerin with the acid takes place with the loss of water—a double atom of water being separated for every equivalent of acid. Thus :—

$$\underbrace{C_6H_8O_6}_{\text{Glycerin.}} + \underbrace{C_4H_4O_4}_{\text{Acetic acid.}} = 2HO + \underbrace{C_{10}H_{10}O_8}_{\text{Monoacetin.}}$$

$$C_6H_8O_6 + 2(C_4H_4O_4) = 4HO + \underbrace{C_{14}H_{12}O_{10}}_{\text{Diacetin.}}$$

$$C_6H_8O_6 + 3(C_4H_4O_4) = 6HO + \underbrace{C_{18}H_{14}O_{12}}_{\text{Triacetin.}}$$

Besides combining glycerin with the fatty acids, Berthelot has obtained combinations with the mineral acids. A brief notice of the hydrochloric and nitric acid compounds will be given here ; and most of the glycerides will be described under their respective heads. But for further information on the subject, the reader must be referred to the original papers of Berthelot which have appeared in the 'Annales de Chimie et Physique,' vols. xli and xliii.

Glycerin forms with hydrochloric acid three combinations, which have been named monochlorhydrin, dichlorhydrin, and trichlorhydrin.

Monochlorhydrin $\left(C_6H_7ClO_4 = \left.\begin{matrix}C_6H_5''' \\ H_2 \\ Cl\end{matrix}\right\}O_4\right)$ is obtained by saturating glycerin with hydrochloric acid gas, and maintaining the solution for a long time at a temperature of 212° Fahr. It is then neutralised with carbonate of soda, and agitated with ether. On evaporating this solution, the body is left as a neutral oil, of a fresh and ethereal odour, and a sweet but fragrant taste. It is miscible with water and ether. Its density is 1·31, and it boils at 441° Fahr. Monochlorhydrin acts on ammonia, and forms the hydrochlorate of a base which Berthelot names *glyceramine*.

$$\underbrace{C_6H_7O_4,Cl}_{\text{Monochlorhydrin.}} + NH_3 = \underbrace{N\left\{\begin{matrix}C_6H_7O_4 \\ H \\ H\end{matrix}\right.}_{\text{Hydrochlorate of glyceramine.}} + HCl$$

Dichlorhydrin $\left(C_6H_6Cl_2O_2 = \left.\begin{matrix}C_6H_5''' \\ H \\ Cl_2\end{matrix}\right\}O_2\right)$ is obtained by exposing a mixture of glycerin with ten to twelve times its bulk of fuming hydrochloric acid to a temperature of 212° Fahr. for several days. It is purified like the preceding compound. It has a strong ethereal odour ; dissolves readily in ether, but with greater difficulty in water than monochlorhydrin. It boils at 352° Fahr. It is decomposed by alkalies into chlorides and glycerin.

Trichlorhydrin, $C_6H_5Cl_3 = \left.\begin{matrix}C_6H_5''' \\ Cl_3\end{matrix}\right\}$ obtained by treating dichlorhydrin with pentachloride of phosphorus ; it is a neutral liquid, boiling at 311° Fahr.

The formation of these ethers may be thus expressed :—

$$\underbrace{C_6H_8O_6}_{\text{Glycerin.}} + HCl = \underbrace{C_6H_7O_4Cl}_{\text{Monochlorhydrin.}} + 2HO$$

$$\underbrace{C_6H_8O_6}_{\text{Glycerin.}} + 2HCl = \underbrace{C_6H_6O_2Cl_2}_{\text{Dichlorhydrin.}} + 4HO$$

$$\underbrace{C_6H_8O_6}_{\text{Glycerin.}} + 3HCl = \underbrace{C_6H_5Cl_3}_{\text{Trichlorhydrin.}} + 6HO$$

Nitroglycerin, Glonoin $\left.\begin{matrix}C_6H_5''' \\ (NO_4)^3\end{matrix}\right\}O^6$, the nitric ether of glycerin. This substance is prepared by gradually adding glycerin to a mixture of sulphuric and fuming nitric acids, carefully cooled. The glycerin dissolves without any disengagement of nitric vapours. On adding water to the solution, nitroglycerin is precipitated as a heavy yellowish oil, soluble in alcohol and ether, with a saccharine and aromatic taste. It is a very instable compound. It decomposes with a loud detonation when heated, and explodes even when struck violently. A solution of nitroglycerin, left to stand for some time, decomposes into glyceric acid. A drop of nitroglycerin placed on the tongue causes a sensation of nausea, which lasts for several hours.

Nitroglycerin appears to possess different properties, according to the mode of its formation. Probably in some cases a basic nitrate is formed.

Glyceric Ether. The replacement of both the hydrogen atoms in alcohol by ethyl produces ether $\left.\begin{matrix}C_4H_5 \\ C_4H_5\end{matrix}\right\}O_2$. The compound exactly corresponding to ether in the series of glycerin is not known, but a substance exists which corresponds to the mixed ethers of Williamson This is *diathylin*. It is prepared by heating a mixture of glycerin, caustic potass, and bromide of ethyl, to a temperature of 100° for several days. It is a colourless limpid oil, with a slightly aromatic ethereal odour. Its sp. gr. is 0·920, and it boils at 376° Fahr. Its formula is $C_{14}H_{16}O_6$, and it is glycerin in which 2 equivalents of hydrogen are replaced by 2 equivalents of ethyl $\left.\begin{matrix}C_6H_5{}'''\\(C_4H_5)_2\\H\end{matrix}\right\}O_6$.

Glycerin, when treated with sulphuric, phosphoric, or tartaric acids, combines with them, forming compounds analogous to sulphovinic, phosphovinic, and tartrovinic acids.

Sulphoglyceric Acid ($C_6H_8S_2O_{12}$). When glycerin is mixed in the cold with double its weight of concentrated sulphuric acid, the two substances combine with considerable elevation of temperature, but without producing any colouring. The mixture is cooled, diluted with water, and then saturated with baryta, by which a crystallisable sulphoglycerate of baryta is formed. By treating a solution of this substance with sulphuric acid, sulphate of baryta is formed, and sulphoglyceric acid set free. The aqueous solution of the latter must be concentrated in vacuo, and the concentration cannot exceed a certain limit, otherwise decomposition takes place, even at 32° Fahr. The sulphoglycerates are mostly soluble in water; they are very readily decomposed by being heated with water or metallic oxides, forming sulphuric acid and glycerin. By dry distillation they are decomposed, with formation of sulphurous acid, acrylic acid, acrolein, &c.

Sulphoglyceric acid is analogous to sulphovinic acid. If this latter be considered as sulphuric acid in which one atom of hydrogen has been replaced by ethyl, then the corresponding compound of glycerin may be represented as sulphuric acid in which one atom of hydrogen is replaced by the monatomic group $C_6H_7O_4$ derived from glycerin. The same remark would apply to phosphoglyceric and tartroglyceric acids. The formation of sulphoglyceric acid is thus expressed:—

$$\underbrace{\left.\begin{matrix}C_6H_7O_4\\H\end{matrix}\right\}O_2}_{\text{Glycerin.}} + \underbrace{\left.\begin{matrix}S_2O_4\\H_2\end{matrix}\right\}O_4}_{\text{Sulphuric acid.}} = \left.\begin{matrix}H\\H\end{matrix}\right\}O_2 + \underbrace{\left.\begin{matrix}S_2O_4\\C_6H_7O_4\\H\end{matrix}\right\}O_4}_{\text{Sulphoglyceric acid.}}$$

Phosphoglyceric acid ($C_6H_8O_6,PO_5HO$). This body is obtained by dissolving glacial phosphoric acid in its weight of syrupy glycerin. The solution is accompanied by considerable rise of temperature. It is then diluted with water, neutralised with baryta, filtered from the insoluble phosphate of baryta, and the concentrated filtrate mixed with solution of acetate of lead, by which an insoluble phosphoglycerate of lead is formed. To obtain the acid, this salt is decomposed with sulphuretted hydrogen, and the filtrate evaporated and concentrated in vacuo. It is an uncrystallisable liquid, which at its state of greatest concentration has the consistence of a thick syrup. In this state it is readily decomposed by an increase of temperature into glycerin and free phosphoric acid.

The phosphoglycerates are generally soluble in water, but little or not at all in alcohol. Their solutions decompose by boiling, especially in the presence of bases, into phosphates and free glycerin.

M. Goblez has found that phosphoglyceric acid in combination with soda and ammonia is contained in the cerebral matter, and in the yolk of egg.

When glycerin is heated with anhydrous phosphoric acid, acrolein is produced. [ACROLEIN.]

GLYCERYL (C_6H_7). The radical formerly assumed to be contained in GLYCERIN, the formula of which was then written $C_6H_7O_5$, HO. Recent researches prove that the compound group, which in glycerin occupies the same position as ethyl in alcohol, is the teratomic radical C_6H_5, to which therefore the above term would now be more appropriately applied.

GLYCOCIN. [GLYCOCOLL.]

GLYCOCOLL, *Glycocin. Sugar of gelatine*, $C_4NH_5O_4$, is a compound found amongst the products obtained by boiling gelatine with potash or acids. It may also be prepared by heating hippuric acid with hydrochloric acid, when benzoic acid, water, and glycocoll are produced. It forms transparent crystals, which are soluble in water and sweet to the taste. It combines with acids and bases. Its easy formation from the animal compound gelatine, has led to the supposition that it may play an important part in the animal body.

GLYCOL ($C_4H_6O_4$). This is the type of a new class of compounds discovered by Wurtz in 1856. In their chemical relations and properties they occupy a place intermediate between the class of alcohols of which common alcohol is the type, on the one hand, and the class of bodies of which glycerin is the type, on the other. The name *glycol* has been given to express this relation, and that of *biatomic alcohol* to express that they have a capacity of saturation double that of common alcohol.

We may consider alcohol as being derived from the type of a double atom of water by the substitution of an equivalent of the monoatomic radical ethyl for an equivalent of hydrogen. [ORGANIC RADICALS.]

If now in *two* double atoms of water we replace *two* eq. of hydrogen by a biatomic radical, such as ethylene, C_4H_4, we shall obtain glycol. The relations of alcohol to glycol may be thus seen.

$$\underbrace{\left.\begin{matrix}C_4H_5\\H\end{matrix}\right\}O_2}_{\text{Alcohol.}} \qquad \underbrace{\left.\begin{matrix}C_4H_4{}''\\H_2\end{matrix}\right\}O_4}_{\text{Glycol.}}$$

By the action of iodide of ethyl, for example, on acetate of silver we obtain iodide of silver and acetic ether. Similarly by the action of the biatomic iodide of ethylene ($C_4H_4I_2$) on two equivalents of acetate of silver we obtain acetate of glycol, the acetic ether of glycol:—

$$\underbrace{2\left(\left.\begin{matrix}C_4H_3O_2\\Ag\end{matrix}\right\}O_2\right)}_{\text{Acetate of silver.}} + \underbrace{C_4H_4{}''I_2}_{\text{Iodide of ethylene.}} = \underbrace{\left.\begin{matrix}C_4H_4{}''\\(C_4H_3O_2)_2\end{matrix}\right\}O_4}_{\text{Acetate of glycol.}} + \underbrace{2AgI}_{\text{Iodide of silver.}}$$

It was by means of this re-action that Wurtz first obtained the acetic ether of glycol, and from the ether, by decomposition with alkalies, glycol itself. The method is suceptible of general application, and by its means Wurtz has already obtained four members of the series: ethyl glycol, propyl glycol, butyl glycol, and amyl glycol.

We shall describe the preparation and properties of the typical member of the group glycol itself. It will not be necessary to enter minutely into a consideration of the others, inasmuch as they present the most perfect homology with glycol, not only in their properties, but in their chemical relations.

For the preparation of glycol, the best method is that proposed by Atkinson. It is a modification of Wurtz's method, and consists in the action of bromide of ethylene on acetate of potash. The products of the re-action are bromide of potassium, free acetic acid, and monoacetate of glycol, as is seen by the equation—

$$\underbrace{2\left(\left.\begin{matrix}C_4H_3O_2\\K\end{matrix}\right\}O_2\right)}_{\text{Acetate of potash.}} + \underbrace{C_4H_4{}''Br_2}_{\text{Bromide of ethylene.}} = \underbrace{\left.\begin{matrix}C_4H_4{}''\\(C_4H_3O_2)\\H\end{matrix}\right\}O_4}_{\text{Monoacetate of glycol.}} + \underbrace{C_4H_4O_4}_{\text{Acetic acid.}} + \underbrace{2KBr}_{\text{Bromide of potassium.}}$$

About 2 ounces of acetate of potash, dissolved in 5 or 6 ounces of alcohol, are placed in a soda-water bottle with 2 ounces of bromide of ethylene: the bottle is lightly corked, and heated for two days on the water-bath. The contents are then filtered from the bromide of potassium, which is washed with ether, and the united filtrates and washings submitted to fractional distillation, those parts being collected which distil above 356° Fahr. On being again rectified, the greater part, consisting of pure monoacetate of glycol, distils over at 360° Fahr.

To obtain glycol, the monoacetate of glycol is mixed with an equivalent quantity of potash, which decomposes it with evolution of heat. The mixture after having been allowed to stand some time, is distilled in the oil bath. On rectifying the distillate, a product is obtained, boiling at 387° Fahr., which is pure glycol. The decomposition of monoacetate of glycol by potash is expressed by the equation:—

$$\underbrace{\left.\begin{matrix}C_4H_4{}''\\C_4H_3O_2\\H\end{matrix}\right\}O_4}_{\text{Monoacetate of glycol.}} + KO\,HO = \underbrace{\left.\begin{matrix}C_4H_4{}''\\H_2\end{matrix}\right\}O_4}_{\text{Glycol.}} + \underbrace{C_4H_3KO_4}_{\text{Acetate of potash.}}$$

The following modification of this method has been used by Debus, and although somewhat tedious it gives a larger product. Monoacetate of glycol mixed with its bulk of water is heated for 12 to 16 hours in a closed vessel to the temperature of boiling water. By this means it is decomposed into free acetic acid and glycol. The liquid is rectified, and the parts collected which distil over above 374° Fahr. This consists principally of glycol, but still contains acetic acid.

An acetic acid determination, by means of baryta, is made in a sample of this liquid, and then the proportionate quantity of potash is added, and the mixture submitted to distillation. The distillate consists of pure glycol.

Pure glycol is an inodorous, somewhat viscid, liquid, with a slightly saccharine taste. It has a density of 1·125 at 32° Fahr. It boils at 386° to 387° Fahr. Exposed to the temperature produced by a mixture of solid carbonic acid and ether, it becomes gummy without solidifying. Its vapour density has been found to be 2·164. The number required by theory is 2·146.

Glycol is perfectly soluble in water and in alcohol, but only slightly so in ether. In this respect it resembles glycerin. In its solvent properties it stands between water and alcohol. In its chemical re-actions it presents, as will be seen, the closest analogy with alcohol.

Glycol is unaltered in the air; but mixed with platinum black it attracts oxygen with such avidity that the platinum becomes incandescent. By regulating the conditions of the experiment, however, so as to produce a slow action, an aqueous solution of glycol is slowly converted into glycolic acid.

Potassium attacks glycol with energy; hydrogen is evolved, and the heat disengaged is so intense as to inflame the gas, and blacken the residue. The action of sodium is less violent—hydrogen gas is disengaged, and the liquid is converted into a solid white mass consisting of *monosodium glycol*, $\left.\begin{matrix}C_4H_4''\\Na\\H\end{matrix}\right\}O_4$. By heating this compound with an additional equivalent of sodium to a temperature of 374° Fahr. another equivalent of hydrogen is replaced by sodium—the *disodium glycol* $\left(\left.\begin{matrix}C_4H_4''\\Na_2\end{matrix}\right\}O_4\right)$ being formed.

Nitric acid oxidises glycol with great energy, with formation of glyoxylic, glycolic, and oxalic acids.

When glycol is fused with hydrate of potash, a large quantity of hydrogen gas is disengaged, and the residue consists principally of oxalate of potash. Alcohol, under similar treatment, yields hydrogen and acetate of potash:

$$\underbrace{\left.\begin{matrix}C_4H_4''\\H_2\end{matrix}\right\}O_4}_{\text{Glycol.}} + 2KO\,HO = \underbrace{\left.\begin{matrix}C_4O_4\\K_2\end{matrix}\right\}O_4}_{\text{Oxalate of potash.}} + 8H$$

The action of pentachloride of phosphorus on glycol is very energetic; the products formed are hydrochloric acid, oxychloride of phosphorus, and chloride of ethylene.

$$\underbrace{\left.\begin{matrix}C_4H_4''\\H_2\end{matrix}\right\}O_4}_{\text{Glycol.}} + \underbrace{2PCl_5}_{\substack{\text{Pentachloride}\\\text{of phosphorus.}}} = \underbrace{C_4H_4''Cl_2}_{\substack{\text{Chloride of}\\\text{ethylene.}}} + \underbrace{2PO_2Cl_3}_{\substack{\text{Oxychloride}\\\text{of phosphorus.}}} + 2HCl$$

Chloride of ethylene is the true hydrochloric ether of glycol—it stands towards it in the same relation as chloride of ethyl to alcohol.

Ethers of glycol.—The ether of glycol is not formed by the ordinary processes of etherification. When glycol is treated with chloride of zinc, aldehyde is formed, and Wurtz was at first inclined to regard this as the ether corresponding to glycol. The true ether is, however, obtained by the action of potash on monohydrochlorate of glycol:—

$$\underbrace{\left.\begin{matrix}C_4H_4''\\H\\Cl\end{matrix}\right\}O_2}_{\substack{\text{Monochlorhydrate}\\\text{of glycol.}}} + KO\,HO = \underbrace{C_4H_4O_2}_{\substack{\text{Glycolic}\\\text{ether.}}} + \underbrace{KCl}_{\substack{\text{Chloride of}\\\text{potassium.}}} + 2HO$$

The action takes place with considerable energy, chloride of potassium is formed, and a gas disengaged which is condensed by means of a freezing mixture to a very mobile liquid, boiling at 56° Fahr. Its vapour density is 1·42. The calculated number is 1·52.

It is isomeric with aldehyde, which it resembles in many respects. It reduces ammoniacal nitrate of silver—but unlike aldehyde, it forms no crystalline compound with ammonia. By the action of pentachloride of phosphorus, glycolic ether yields chloride of ethylene,—

$$\underbrace{C_4H_4O_2}_{\text{Glycolic ether.}} + PCl_5 = PO_2Cl_3 + \underbrace{C_4H_4Cl_2}_{\substack{\text{Chloride of}\\\text{ethylene.}}}$$

By the same treatment, aldehyde yields chloride of aldehydene.

Two mixed ethers, corresponding to the mixed ethers of Williamson, have been obtained from glycol. The first, *ethylglycol* $\left(\left.\begin{matrix}C_4H_4''\\(C_4H_5)\\H\end{matrix}\right\}O_4\right)$, is obtained by the action of iodide of ethyl on monosodium glycol:—

$$\underbrace{\left.\begin{matrix}C_4H_4\\Na\\H\end{matrix}\right\}}_{\substack{\text{Monosodium}\\\text{glycol.}}} + \underbrace{C_4H_5I}_{\substack{\text{Iodide of}\\\text{ethyl.}}} = \underbrace{\left.\begin{matrix}C_4H_4''\\(C_4H_5)\\H\end{matrix}\right\}O_4}_{\text{Ethylglycol.}} + \underbrace{NaI}_{\substack{\text{Iodide of}\\\text{sodium.}}}$$

When monoethylglycol is treated with potassium, hydrogen is liberated and a white solid mass formed, which, when treated with iodide of ethyl, yields *diethylglycol*:—

$$\left.\begin{matrix}C_4H_4''\\C_4H_5\\K\end{matrix}\right\}O_4 + \underbrace{C_4H_5I}_{\substack{\text{Iodide of}\\\text{ethyl.}}} = \underbrace{KI}_{\substack{\text{Iodide of}\\\text{potassium.}}} + \underbrace{\left.\begin{matrix}C_4H_4''\\(C_4H_5)_2\end{matrix}\right\}O_4}_{\text{Diethylglycol.}}$$

Diethylglycol is a colourless mobile liquid, with an agreeable ethereal odour. Its sp. gr. is 0·7993, and its vapour density, 4·095. Theory requires 4·085. Its boiling point is 254° Fahr. In this respect it differs from acetal, with which it is isomeric, which boils at 217° Fahr.

Compound ethers of glycol.—The compound ethers of the alcohol series are formed by the union of

Alcohol + acid — 2 at. Water.

as in the formation of acetic ether:—

$$\underbrace{C_4H_6O_2}_{\text{Alcohol.}} + \underbrace{C_4H_4O_4}_{\text{Acetic acid.}} - 2HO = \underbrace{\left.\begin{matrix}C_4H_5\\(C_4H_3O_2)\end{matrix}\right\}O_2}_{\text{Acetic ether.}}$$

In an analogous manner the compound ethers of glycol are derived by the union of glycol + 2 at. acid — 4 at. water, as in the formation of acetate of glycol:—

$$\underbrace{C_4H_6O_4}_{\text{Glycol.}} + \underbrace{2C_4H_4O_4}_{\text{Acetic acid.}} - 4HO = \underbrace{\left.\begin{matrix}C_4H_4''\\(C_4H_3O_2)_2\end{matrix}\right\}O_4}_{\text{Acetate of glycol.}}$$

In saponifying, the compound ethers of alcohol assimilate 2 at. water whilst the compound ethers of glycol assimilate 4 at. water. The compound ethers of glycol are in general prepared by the action of the iodide or bromide of ethylene on the corresponding silver salt.

Acetate of glycol $\left(C_{12}H_{10}O_8=\left.\begin{matrix}C_4H_4''\\(C_4H_3O_2)_2\end{matrix}\right\}O_4\right)$; is formed by the action of iodide or bromide of ethylene on acetate of silver in the presence of free acetic acid. It is a colourless neutral liquid, with a slight acetic odour. It boils at 367° Fahr. It dissolves in 7 volumes of water at 71° Fahr.

Monoacetate of glycol $\left(C_8H_8O_6=\left.\begin{matrix}C_4H_4''\\C_4H_3O_2\\H\end{matrix}\right\}O_4\right)$. The preparation and properties of this body have been already described. It is also formed when anhydrous acetic acid acts on glycol. When heated for some time in a closed vessel with water, it is decomposed into glycol and free acetic acid.

Butyrate of glycol $\left(C_{20}H_{18}O_8=\left.\begin{matrix}C_4H_4''\\(C_8H_7O_2)_2\end{matrix}\right\}O_4\right)$ is formed by the action of bromide of ethylene on butyrate of silver in the presence of free butyric acid. The product of the action is treated with ether and the ethereal solution distilled and rectified. Butyrate of glycol is a colourless liquid, with a somewhat butyric odour, boiling at about 464° Fahr. and distilling without alteration. It is quite insoluble in water, but completely so in alcohol and ether.

Stearate of glycol $\left(C_{76}H_{74}O_8=\left.\begin{matrix}C_4H_4''\\(C_{36}H_{35}O_2)_2\end{matrix}\right\}O_4\right)$, obtained by the action of bromide of ethylene on stearate of silver, consists of brilliant small laminæ, fusible at 169° Fahr., and closely resembling stearin.

Benzoate of glycol $\left(C_{32}H_{14}O_8=\left.\begin{matrix}C_4H_4''\\(C_{14}H_5O_2)_2\end{matrix}\right\}O_4\right)$ is prepared like the preceding ethers. It presents the form of colourless, right rhomboidal prisms, which fuse at 153° Fahr., and distil without alteration at a point beyond the ordinary range of the thermometer.

Hydrochloric ethers of glycol. The neutral hydrochloric ether of glycol, and that which stands to glycol in the same relation as chloride of ethyl to alcohol, is the oil of olefiant gas, or chloride of ethylene $C_4H_4Cl_2$. It may be conceived as being derived from glycol by the replacement of 2 eq. of peroxide of hydrogen by 2 eq. chlorine. From the constitution of glycol, it is evident that there may be an ether intermediate between chloride of ethylene and glycol,—in fact glycol in which one eq. of peroxide of hydrogen is replaced by chlorine. The relation of these bodies may be seen from the scheme:—

$$\underbrace{\left.\begin{matrix}C_4H_4''\\H\\H\end{matrix}\right\}O_4}_{\text{Glycol.}} \qquad \underbrace{\left.\begin{matrix}C_4H_4''\\H\\Cl\end{matrix}\right\}O_2}_{\substack{\text{Monochlorhydrate}\\\text{of glycol.}}} \qquad \underbrace{\begin{matrix}C_4H_4''\\Cl_2\end{matrix}}_{\substack{\text{Chloride of}\\\text{ethylene.}}}$$

The body in question has been termed the chlorhydrin of glycol.

It is formed by the action of hydrochloric acid on glycol, and is a colourless liquid, boiling at 262° Fahr. By the action of potash it gives oxide of ethylene.

Chloracetine of glycol $(C_8H_7ClO_4)$. This body is formed by the concurrent action of hydrochloric acid and acetic acid on glycol. It is a colourless liquid, heavier than water, and boiling at 293° Fahr., without decomposition. It is intermediate between chloride of ethylene and acetate of glycol. Its formation may be thus expressed:—

$$\underbrace{\left.\begin{matrix}C_4H_4''\\H_2\end{matrix}\right\}O_4}_{\text{Glycol.}} + \underbrace{\left.\begin{matrix}C_4H_3O_2\\H\end{matrix}\right\}O_2}_{\text{Acetic acid.}} + HCl = \underbrace{\left.\begin{matrix}C_4H_4''\\(C_4H_3O_2)\\Cl\end{matrix}\right\}O_2}_{\text{Chloracetin of glycol.}} + 4HO$$

It is also formed by the action of hydrochloric acid on monoacetate o glycol.

It is decomposed by potash, with formation of acetate and chloride of potassium.

Chlorbutyrin of glycol and chlorbenzoin of glycol are compounds quite analogous to this, and are prepared by similar methods.

Butyroacetate of glycol. This is glycol in which one atom of hydrogen is replaced by the radical acetyl, and another by butyryl. It is a substance with a bitter pungent taste, heavier than water, and boiling at 410° Fahr. It is formed by the action of chloracetin of glycol on butyrate of silver.

$$\underbrace{\left.\begin{matrix}C_4H_4''\\C_4H_3O_2\\Cl\end{matrix}\right\}O_2}_{\substack{\text{Chloracetin}\\\text{of glycol.}}} + \underbrace{\left.\begin{matrix}C_8H_7O_2\\Ag\end{matrix}\right\}O_2}_{\substack{\text{Butyrate of}\\\text{silver.}}} = \underbrace{\left.\begin{matrix}C_4H_4''\\C_4H_3O_2\\C_8H_7O_2\end{matrix}\right\}O_4}_{\substack{\text{Butyroacetate}\\\text{of glycol.}}} + \underbrace{AgCl}_{\substack{\text{Chloride}\\\text{of silver.}}}$$

It is evident that many such analogous compounds may be formed.

By the action of hydriodic acid on glycol, iodide of ethylene is formed:

$$\underbrace{\left.\begin{matrix}C_4H_4''\\H_2\end{matrix}\right\}O_4}_{\text{Glycol.}} + \underbrace{2HI}_{\text{Hydriodic acid.}} = \underbrace{\left.\begin{matrix}C_4H_4''\\I_2\end{matrix}\right\}}_{\text{Iodide of ethylene.}} + 4HO$$

By modifying the action of hydriodic acid, an iodhydrin of glycol $\left(\left.\begin{matrix}C_4H_4''\\H\\I\end{matrix}\right\}O_2\right)$, corresponding to the chlorhydrin, appears to be formed. There is also an iodacetin of glycol analogous both in preparation and properties to the chloracetin of glycol.

Sulphoglycolic acid. Sulphuric acid by its action on glycol forms a compound analogous to sulphovinic acid, which has however hitherto only been examined in the baryta salt. Equivalent quantities of glycol and sulphuric acid are mixed together, heated for some time, diluted, neutralised with carbonate of baryta, and evaporated.

Sulphoglycolate of baryta is a somewhat deliquescent salt. Sulphuric acid precipitates sulphate of baryta from its aqueous solution, but baryta water produces no precipitate—at least not in the cold. The formation of sulphoglycolic acid may be thus expressed.

$$\underbrace{\left.\begin{matrix}C_4H_4''\\H_2\end{matrix}\right\}O_4}_{\text{Glycol.}} + 2SO_4H = \underbrace{\left.\begin{matrix}C_4H_5O_2\\S_2O_4\\H\end{matrix}\right\}O_4}_{\text{Sulphoglycolic acid.}} + 2HO$$

When the acid is neutralised by carbonate of baryta, hydrogen is replaced by barium, and we have the salt, $\left.\begin{matrix}C_4H_5O_2\\S_2O_4\\Ba\end{matrix}\right\}O_4$. Sulphoglycolic acid is monobasic.

Glyoxal and glyoxylic acid.—These are two bodies, the former an aldehyde, and the latter an acid, discovered by Debus, among the products of the oxidation of alcohol by nitric acid. As they belong to the glycol series a brief description of them is here necessary, while for fuller details the reader is referred to Debus' original papers ('Phil. Mag.,' vol. xii. p. 361).

Glyoxal ($C_4H_2O_4$), when pure, is a solid, amorphous, pale-yellowish mass, which deliquesces in the air, and is very soluble in alcohol and ether. It has all the properties of an aldehyde, it reduces silver salts, and forms crystalline compounds with alkaline bisulphites, from which glyoxal is obtained by treatment with dilute acids. The action of ammonia on glyoxal yields two well-defined crystallised bodies, *glycosine* and *glyoxaline*.

Glycosine ($C_{12}H_6N_4$) forms a light white, inodorous, and tasteless white powder, which can be sublimed without change. Its hydrochlorate forms crystals, frequently an inch long. Its platinum salt has the formula, $C_{12}H_6N_4$, 2HCl, $2PtCl_2$. The formation of glycosine from glyoxal and ammonia is analogous to that of amarine from oil of bitter almonds and ammonia, and may be expressed by the equation:—

$$\underbrace{3(C_4H_2O_4)}_{\text{Glyoxal.}} + 4NH_3 = \underbrace{C_{12}H_6N_4}_{\text{Glycosine.}} + 12HO$$

Glyoxaline ($C_6H_4N_2$) crystallises with difficulty; its acid oxalate forms colourless prisms, and its platinum salt, $C_6H_4N_2$, HCl, $PtCl_2$, crystallises in splendid orange-red prisms.

Its formation may be represented by the equation:—

$$\underbrace{2(C_4H_2O_4)}_{\text{Glyoxal.}} + 2NH_3 = \underbrace{C_6H_4N_2}_{\text{Glyoxaline.}} + \underbrace{C_2H_2O_4}_{\text{Formic acid.}} + 4HO$$

Glyoxylic acid, $C_4H_4O_8$, appears on the evaporation of its aqueous solution in vacuo, in the form of a tough, transparent, pale-yellowish syrup, which neither crystallises nor solidifies. Its aqueous solution decomposes carbonates, and saturates strong bases. It is volatile without decomposition. Glyoxylic acid is a monobasic acid. Its salts have the general formula, $C_4H_3MO_8$. They mostly crystallise well.

Glyoxal is the aldehyde of glycol; it is intermediate between glycol and oxalic acid, and occurs among the products of the direct oxidation of glycol. Its analogy to common aldehyde is well seen in the mode of its formation:—

$$\underbrace{C_4H_6O_2}_{\text{Alcohol.}} + 2O = \underbrace{C_4H_4O_2}_{\text{Aldehyde.}} + 2HO$$

$$\underbrace{C_4H_6O_4}_{\text{Glycol.}} + 4O = \underbrace{C_4H_2O_4}_{\text{Glyoxal.}} + 4HO$$

Glyoxylic acid is an intermediate compound between glycolic and oxalic acids, just as oil of bitter almonds is intermediate between benzylic alcohol and benzoic acid:—

$$\underbrace{C_4H_4O_6}_{\text{Glycolic acid.}} \qquad\qquad \underbrace{C_{14}H_8O_2}_{\text{Benzylic alcohol.}}$$

$$\underbrace{C_4H_2O_6}_{\text{Glyoxylic acid.}} \qquad\qquad \underbrace{C_{14}H_6O_2}_{\text{Oil of bitter almonds.}}$$

$$\underbrace{C_4H_2O_8}_{\text{Oxalic acid.}} \qquad\qquad \underbrace{C_{14}H_6O_4}_{\text{Benzoic acid.}}$$

Glyoxylic acid when decomposed by alkalies, splits up into a glycolate and an oxalate; it also readily absorbs oxygen, and passes into oxalic acid. These decompositions are the exact analogues of those which oil of bitter almonds experiences under the same conditions.

These properties and re actions of glycol prove its complete resemblance to alcohol: and it may be expected that to every monobasic alcohol, a biatomic alcohol or glycol will be found to correspond. Besides glycol, three have been already discovered, propylic glycol, butylic glycol, and amylic glycol, corresponding respectively to a monoatomic alcohol:—

$$\underbrace{C_4H_6O_2}_{\text{Alcohol.}} \qquad\qquad \underbrace{C_4H_6O_4}_{\text{Glycol.}}$$

$$\underbrace{C_6H_8O_2}_{\text{Propylic alcohol.}} \qquad\qquad \underbrace{C_6H_8O_4}_{\text{Propylic glycol.}}$$

$$\underbrace{C_8H_{10}O_2}_{\text{Butylic alcohol.}} \qquad\qquad \underbrace{C_8H_{10}O_4}_{\text{Butylic glycol.}}$$

$$\underbrace{C_{10}H_{12}O_2}_{\text{Amylic alcohol.}} \qquad\qquad \underbrace{C_{10}H_{12}O_4}_{\text{Amylic glycol.}}$$

They are derived respectively from propylene, C_6H_6; butylene, C_8H_8; and amylene, $C_{10}H_{10}$; the homologues of olefiant gas. These latter substances, which are true biatomic radicals, by treatment with bromine form biatomic bromides, $C_6H_6''Br_2$, $C_8H_8''Br_2$, and $C_{10}H_{10}''Br_2$, and these bromides, by acting on 2 eq. acetate of silver, yield the acetate of the corresponding glycol, from which, by treatment with potash, the glycol is obtained.

The homologous series of alcohols exhibit a certain regularity in their boiling points. For every increase of C_2H_2 there is an increase of 34° Fahr. in the boiling point. The glycols exhibit a similar but inverse relation. The boiling points have hitherto been determined in most cases in too small quantities of substance to be considered as quite accurate, nevertheless a certain regularity has been observed. The higher a glycol stands in the series, the *lower* are its boiling point and density. Thus:—

		Density.	Boiling Point.
Glycol . . .	$C_4H_6O_4$	1·125	387° Fahr.
Propylic glycol . .	$C_6H_8O_4$	1·051	372° „
Butylic glycol . .	$C_8H_{10}O_4$	1·048	361° „
Amylic glycol . .	$C_{10}H_{12}O_4$	0·987	350° „

To each member of the series of homologous monoatomic alcohols, there is a corresponding acid, a member of the fatty acid series; and similarly there is a homologous series of acids parallel with the glycols, and which are derived from them by direct oxidation:—

$$\underbrace{C_4H_6O_4}_{\text{Glycol.}} + 4O = \underbrace{C_4H_4O_6}_{\text{Glycolic acid.}} + 2HO$$

$$\underbrace{C_6H_8O_4}_{\text{Propylic glycol.}} + 4O = \underbrace{C_6H_6O_6}_{\text{Lactic acid.}} + 2HO$$

$$\underbrace{C_8H_{10}O_4}_{\text{Butylic glycol.}} + 4O = \underbrace{C_8H_8O_6}_{\text{Butylactic acid.}} + 2HO$$

The acid corresponding to amylic glycol has not been discovered. On the other hand, leucic acid ($C_{12}H_{12}O_6$), which has long been recognised as a homologue of lactic acid, probably corresponds to a glycol hitherto undiscovered, caprylic glycol, $C_{12}H_{14}O_4$.

The acetate of methylic glycol has been prepared from iodide of methylene, $C_2H_2''I_2$. It has the formula $\left.\begin{matrix}C_2H_2''\\(C_4H_3O_2)^2\end{matrix}\right\}O_4$. It has not been possible to obtain from it methylic glycol, as by treatment with bases it is completely decomposed.

A series of bodies has been obtained by Wicke, which are considered to be derivatives of a glycol of the benzoic acid series. By the action of chlorobenzole ($C_{14}H_6''Cl_2$) on acetate of silver, a substance is obtained which has the formula $\left.\begin{matrix}C_{14}H_6''\\(C_4H_3O_2)^2\end{matrix}\right\}O_4$. This would be the formula of the acetate of a glycol, $C_{14}H_8O_4$, corresponding to benzöylic alcohol ($C_{14}H_8O_2$). But Wicke has not been able to prepare the glycol itself, from the tendency the compound has of producing benzoic aldehyde when decomposed by bases. The body exhibits in several instances re-actions, deviating from those of the ordinary glycols, and until the subject has been further examined, it cannot be considered as the derivative of a true glycol. A similar compound has been obtained from the cumol series.

The further study of the glycols and their derivatives may be expected to throw light on many bodies whose relations are at present obscure or unknown. Probably meconin and saligenin will be found to be biatomic alcohols. Berthelot has obtained a combination of stearic acid with meconin, which has the formula :—

$$\left.\begin{matrix}(C_{20}H_8O_4)''\\(C_{36}H_{35}O_2)^2\end{matrix}\right\}O_4$$

And saligenin, $C_{14}H_8O_4$, appears to be the glycol corresponding to salicylic acid, $\left.\begin{matrix}C_{14}H_6''\\H_2\end{matrix}\right\}O_4$.

GLYCOLIC ACID ($C_4H_4O_6$). This acid is the lowest member of the series of acids to which *lactic* and *leucic acids* belong, and recent researches have established a close relation between it and glycol.

It is formed by a variety of processes. It was first obtained by the action of nitrous acid on glycocoll. An aqueous solution of glycocoll is saturated with nitrous acid, and the solution extracted with ether; on the evaporation of the ethereal solution, the acid is left in the form of a thick syrup. The action is analogous to that by which alanin, the homologue of glycocoll, is converted into lactic acid :—

$$\underbrace{C_4H_5NO_4}_{\text{Glycocoll.}} + \underbrace{NO_3}_{\text{Nitrous acid.}} = \underbrace{C_4H_4O_6}_{\text{Glycolic acid.}} + 2N + HO$$

Glycolic acid also occurs among the products of the oxidation of alcohol by nitric acid. It is also formed by the oxidation of glycol.

Another mode of its formation also shows its relation to lactic acid. When tartraric acid ($C_6H_4O_{10}$), an acid produced by the spontaneous decomposition of nitrotartaric acid, is heated, it decomposes into water, carbonic acid, and *glycollide* :—

$$\underbrace{C_6H_4O_{10}}_{\text{Tartraric acid.}} = \underbrace{C_4H_2O_4}_{\text{Glycollide.}} + 2HO + 2CO_2$$

Glycollide stands to glycolic acid in the same relation as lactide to lactic acid: it is the anhydride of glycolic acid. When it is digested for some time in the warm with water, it assimilates 2 eq. of water, and becomes converted into glycolic acid.

Perhaps the best method of preparing glycolic acid is by the spontaneous decomposition of chloracetic acid. When an aqueous solution of chloracetate of potash is heated in a closed vessel to between 250° and 280° Fahr., chloride of potassium is formed, and the solution contains glycolic acid :—

$$\underbrace{C_4H_2ClKO_4}_{\text{Chloracetate of potash.}} + 2HO = \underbrace{C_4H_4O_6}_{\text{Glycolic acid.}} + \underbrace{KCl}_{\text{Chloride of potassium.}}$$

Glycolic acid, in its state of greatest concentration, has the form of a thick syrup, which, dried in vacuo over sulphuric acid, forms long well-defined crystals. It is miscible with water, alcohol, and ether, in all proportions. Its aqueous solution decomposes carbonates. The zinc salt has the formula $C_4H_3ZnO_6 + 2$ aq., and greatly resembles the corresponding lactate of zinc. When glycolic acid is mixed with acetate of lead, and excess of ammonia added, a white precipitate is formed. By this deportment it is distinguished from lactic acid, which, under the same circumstances, remains clear. *Glycolate of lime* ($C_4H_3CaO_6$) crystallises from a hot aqueous solution in stellate groups of very fine asbestos-like needles. It is quite insoluble in alcohol, even when dilute, and is hence easily separated from lactate of lime, which is soluble.

Glycolic acid stands in the same relation to glycol as acetic acid to alcohol. Both acids are derived from their corresponding alcohols by direct oxidation :—

$$\underbrace{C_4H_6O_2}_{\text{Alcohol.}} + O_4 = \underbrace{C_4H_4O_4}_{\text{Acetic acid.}} + 2HO$$

$$\underbrace{C_4H_6O_4}_{\text{Glycol.}} + O_4 = \underbrace{C_4H_4O_6}_{\text{Glycolic acid.}} + 2HO$$

When the oxidation of glycol is more energetic, oxalic acid is formed. These two acids represent, in a certain sense, the degrees of oxidation of glycol. Thus—

$$\underbrace{\left.\begin{matrix}C_4H_4''\\H_2\end{matrix}\right\}O_4}_{\text{Glycol.}} \qquad \underbrace{\left.\begin{matrix}C_4H_2O_2''\\H_2\end{matrix}\right\}O_4}_{\text{Glycolic acid.}} \qquad \underbrace{\left.\begin{matrix}C_4O_4''\\H_2\end{matrix}\right\}O_4}_{\text{Oxalic acid.}}$$

In accordance with this view, glycolic acid must be bibasic. Hitherto only monobasic salts have been formed. Its homologue, however, lactic acid (which is a derivative of propylglycol, the homologue of glycol), is bibasic, and it is to be expected that further researches will establish the bibasicity of glycolic acid. [GLYCOL.]

GLYCOLLAMIDE. [GLYCOLLIDE.]

GLYCOLLIDE ($C_4H_2O_4$). This body stands in the same relation to glycollic acid as lactide does to lactic acid, and is formed by the action of heat upon tartronic acid :—

$$\underbrace{C_6H_4O_{10}}_{\text{Tartronic acid.}} = C_2O_4 + \underbrace{C_4H_2O_4}_{\text{Glycollide.}} + 2HO$$

It is a white tasteless powder, insoluble in cold water, and very slightly so in hot. Treated with ammonia, it is transformed into *glycollamide* :—

$$\underbrace{C_4H_2O_4}_{\text{Glycollide.}} + NH_3 = \underbrace{C_4H_5NO_4}_{\text{Glycollamide.}}$$

Glycollamide forms fine colourless crystals, very soluble in water, sparingly soluble in alcohol, and possessing a slightly sweet taste. It is isomeric with sugar of gelatin.

GLYCOCHOLALIC ACID. [CHOLIC ACID.]

GLYCOCHOLIC ACID. [CHOLIC ACID.]

GLYCOSINE. [GLYCOL, *Glycosine.*]

GLYCYL ($C_6H_5O_2$). A hypothetical radical, supposed to be contained in GLYCERIN, whose formula then becomes $\left.\begin{matrix}C_6H_5O_3\\H\end{matrix}\right\}O_2 + \left.\begin{matrix}H\\H\end{matrix}\right\}O_2$.

GLYCYRHIZA GLABRA, and *G. echinata*, liquorice, of which the root, or rather the rhizoma, and a watery extract are officinal. These are natives of Germany and south of Europe, but cultivated extensively in some parts of Britain; the extract is however chiefly prepared in Spain, Italy, and Sicily, and imported under the name of Spanish juice or liquorice: the finest is called Solazzi. The rhizoma is generally allowed to attain the age of three years, and is then taken up. It is often several feet in length, and about half an inch thick. The odour is faint, the taste sweet but mawkish; and if the bark be chewed, it is at last rather acrid, which is owing to the presence of a soft resin, or oleo-resin.

Robiquet found it to contain a peculiar sugar, which is uncrystallisable and unfermentable, called *glycion*, or *glycyrhizin*, and other matters.

Infused in warm, or macerated in cold water, it affords a mucilaginous fluid, which is bland and demulcent. The powder is much used to involve recently made pills, in order to prevent them from adhering to each other. Before using it for an infusion, or to powder it, the bark should be removed, by which the bitterness is avoided.

The extract is formed into rolls from 6 to 8 inches long, which are dried, and surrounded with bay leaves, to prevent them from adhering, as in warm weather they have a tendency to melt, notwithstanding the addition to them of starch or peas-meal: 100 lbs. of the dried root yield 30 lbs. of extract.

Good liquorice juice is black, dry, easily broken (in cold weather), with a shining fracture. It should dissolve easily and entirely in the mouth when pure; but crude liquorice, besides starch or meal, has generally more or less copper, rarely brass, derived from the pans in which it has been boiled; it is therefore subjected to a process of purification, and is then termed *refined* liquorice. This is done by melting it in water, draining off the solution, so as to leave the sand and other impurities behind, and inspissating it; then forming it into more slender cylinders, which are generally soft and moist, even when sugar has been added to them: a better addition is a small quantity of gum arabic. In Yorkshire an extract is prepared which is sold under the name of Pontefract cakes.

Both the crude Spanish and refined liquorice are used as demulcents, to allay tickling cough in slight cases of catarrh: often formed into lozenges, plain or medicated. The *Trochisci glycyrrhizæ cum opio* avowedly contain opium, but too many of the nostrums sold as cough lozenges contain *morphia* to a considerable extent, and are therefore dangerous when too freely used.

GLYCYRRHIZIN ($C_{16}H_{12}O_6$, or $C_{36}H_{24}O_{14}$). An unfermentescible saccharine matter contained in liquorice root. It is a brown translucent amorphous substance, only slightly soluble in cold water, and possessing a nauseous, saccharine, but slightly bitter, taste. Its hot solutions gelatinise on cooling.

GLYOXALINE. [GLYCOL, *Glyoxaline.*]

GLYOXYLIC ACID. [GLYCOL, *Glyoxylic acid.*]

GLYPTOGRAPHY. [ELECTRO-METALLURGY.]

GNOMIC POETS OF GREECE. Under this title are included those moral and philosophical poets whose remains consist chiefly of short sententious precepts or reflections. Such are the Gnomæ of Theognis, which, though numbered consecutively as a connected poem to 1200 lines, form in fact a collection of unconnected members, varying from two to thirty lines in length. Such also were the sentences inscribed by Hipparchus on the Hermæ in the streets of Athens. These metrical precepts were valuable before writing became common; being, like proverbs, serviceable and easily-remembered rules of conduct. This notion of a pithy saying, or apophthegm, is one of the meanings of *γνώμη* (gnóme), whence comes the adjective γνωμικός (gnomikos), relating to gnóme. Winterton's 'Poetæ Minores Græci' (Cambridge, 1677, and later editions) contains a collection of the Gnomic poets. They have also been edited by Brunck ('Gnomici Poetæ Græci,' Argent., 1784, 4to.). The principal authors contained in this edition are Theognis, Tyrtæus, Solon, Simonides, with many others, some to the extent only of a few lines. Tyrtæus and Simonides, however, though the authors of Gnomæ, hardly come under the definition above given, or under any other definition which accurately characterises Theognis and others. Brunck's edition contains also a collection of Gnomæ from the comic writers.

The Gnomic writers are sometimes all classed under the general name of Elegiac poets. [ELEGY.]

GNOMON (the Greek *γνώμων*), or style of a dial, is the plate which projects from the surface of the dial-plate, the edge of its shade determining the hour-line. The plates now in use being flat, the gnomon is in the plane of the meridian, and its sloping edge forms an angle with the horizon equal to the latitude of the place, and is consequently parallel to the axis of the earth. No sensible error is made by confounding the edge of the gnomon with the earth's axis; but in lunar dials a sensible error would arise, except in places of which the latitude is nearly 90°: this error, in either case, depends upon the parallax of the luminous body, and the position of the dial-plate. The ancients, who used hemispherical dial-plates, placed the radius which threw the shade in the direction of the north pole-star, and therefore the hour-lines were circular arcs, at regular intervals of 15°. Herodotus says (ii. 109) that the Greeks borrowed the gnomon and the sphere (*πολος*) from the Babylonians.

The science of gnomonics, upon which many formal treatises have been written, has declined as the theory of astronomy has advanced towards correctness. In the succeeding article one method of construction of a dial will be briefly explained. It is not worth while to enter upon the details of constructions which are now of no use. A sun-dial may be sufficiently well adjusted to give the time within a few minutes, provided the observer has an almanac, or some other work in which the equation of time is contained, by which the indications of the sun are made to agree with those of the clock. [SUN; SUN-DIAL.]

GNOMONIC PROJECTION. The gnomonic projection of any portion of a sphere is that which is constructed on the supposition that the eye is in the centre of the sphere. The consequence is, that any great circle whatsoever of the sphere is projected into a straight line; which property can belong to no other projection.

The most convenient method of projecting the whole sphere gnomonically is to imagine a cube inscribed about it, on each face of which one-sixth part of the sphere is projected, by lines drawn through the centre. The maps of the earth and of the stars published by the Society for the Diffusion of Useful Knowledge are drawn in this manner, a full account of which may be found in the 'Explanation of the Maps of the Stars' (Baldwin, 1836). The result is six maps, which embrace the whole sphere; the shortest distance from any one point to another on the sphere being projected into the shortest distance between their corresponding points on the map, when they lie on the same map.

The gnomonic projection derives its name from the connection between the methods of describing it and those for the construction of a gnomon or dial. The direction in which the shadow of a line parallel to the axis of the earth will be thrown is the intersection of the hour circle for the time being with the surface of the dial (whether plane or not). Imagine a sphere, and the surface of the dial drawn through its centre. Upon this sphere describe the heavens, and project the whole upon a circumscribed cube. Nothing is more easy than to draw the hour circle upon such a projection, and if the intersection of the surface of the dial with the cube be traced out upon the cube, the points at which the projections of the hour circles meet the intersection of the cube and the dial are those towards which the shadow of the axis will point at the hour in question. When a dial is to be constructed geometrically, this is the most simple plan: but calculation, as in other instances, is superior to construction for purposes of accuracy.

GNOSTICS, derived from the Greek word *gnōsis* (*γνώσις*), "knowledge," was employed by the fathers of the first two centuries as a generic term to designate all individuals who professed to interpret the Scriptures by the aid of philosophy. It is supposed from various passages in the New Testament (Col. ii. 8; 1 Tim. i. 4; vi. 20; 2 Tim. ii. 16, 17; Titus, iii. 9; 1 John, ii. 18) that the doctrines of the Gnostics were taught in the times of the Apostles; and the Nicolaitans, who are condemned by St. John (Rev. ii. 6, 15), are looked upon by the fathers as forming a sect of the Gnostics. Many of the fathers considered Simon Magus, Dositheus, and Menander to be the first individuals who propagated Gnostic opinions; but they are more correctly classed by others among the opponents rather than the corrupters of Christianity. The principal teachers of Gnosticism were Saturninus, Basilides, Cerinthus, Carpocrates, and Prodicus, of whom the most celebrated were Cerinthus and Carpocrates; and some of their tenets were held on the authority of passages in the apocryphal gospels of the New Testament. Irenæus ('Adv. Hæres.' iii. 11) states that St. John wrote his gospel in order to refute the errors of Cerinthus; but many critics reject this testimony of Irenæus, and maintain that Cerinthus lived in the second century. The Ebionites also [EBIONITES] are supposed to have been Gnostics.

The origin of the Gnostic system has been traced to various sources. Some have derived their doctrines from the Alexandrian school of philosophy; others from the Jewish Cabbala [CABBALA]; and a still greater number from the Oriental belief in two great independent principles, one the author of good, and the other of evil. Many parts of the Gnostic system may be alleged in favour of each of these suppositions; but it seems to be forgotten that Gnosticism is merely a generic term, and that it included many sects that differed considerably from each other: we should therefore regard it rather as derived from all these ancient systems than formed from any one in particular. For the reasons that have already been mentioned, it is difficult to give an account of their opinions that will apply equally to all the sects into which the Gnostics were divided; but the following abstract contains the doctrines which were regarded by the fathers as characteristic of Gnosticism.

One of the chief sections considered it beneath the might of the Supreme Deity to labour, and therefore maintained that God could not have created the world. They believed that God dwelt in a *plērōma* (*πλήρωμα*) of inaccessible light, and that he was unknown to the world before the coming of Christ; that he created two other beings, called *Æons*, or emanations; that from these other Æons were descended, at the head of whom was one named *Demiurgus*, who created the world; that this Demiurgus was the God of the Old Testament; that Christ, who was one of the Æons, was sent into the world to restore men to the *gnosis* (knowledge) of the true God; that the Æon Christ descended into the man Jesus at his baptism, and left him when he was led to crucifixion, so that the man Jesus alone suffered. This was in effect the belief of the Gnostics of the Jewish Alexandrian school. Another branch, probably of previous oriental converts opposed to Judaism, maintained that the Demiurgus was entirely antagonistic to the Supreme Deity, and that this was shown in the Old Testament; that all matter was intrinsically evil; that the incarnation of Christ was undertaken to relieve mankind from this position; and that an individual at his death was raised to inhabit the divine pleroma, into which corruptible and sinful matter could not enter.

Their doctrines are said to have produced very opposite effects upon their moral conduct; some, looking upon the body as sinful, mortified it by severe penances; while others, with the same opinion, led immoral lives, maintaining that the soul could not be affected by the acts of the body.

(Neander, *Kirchengeschichte*; Mosheim, *Ecclesiastical History*; Lardner's *History of Heretics*; Möhler, *Versuch über den Ursprung der Gnostiker*, 1831; Baur, *Die Christlichen Gnosis in geschichtliche Entwickclung*, 1835.)

GOITRE. [BRONCHOCELE.]

GOLD (Au) is a metal which has been known from the remotest antiquity, and has been universally employed as a medium of exchange. Although the quantity of gold which is found, when compared with that of other metals, is small, yet it occurs in greater or less abundance in almost every part of the globe. It occurs in the native state, and alloyed with silver, also occasionally combined with tellurium, and frequently mixed with metallic sulphurets and arseniurets. It is indeed stated by Gahn that but little sulphuret of iron is met with which does not contain some gold. A large quantity of gold is obtained from South America; the richest mines of Europe are those in Hungary; it has been found also in the sand of the Rhône, the Rhine, and the Danube; small quantities are occasionally found in the stream tin-works of Cornwall; and in Wicklow in Ireland, and the lead-hills of Scotland, no inconsiderable portions have been from time to time collected. But by far the largest supplies of this metal are now derived from Australia and California. Gold is also met with in tolerably large quantity in the Uralian mountains of Siberia.

Native gold occurs crystallised, capillary, and massive; the primary form is a cube. It gives no cleavage; fracture hackly; hardness 2·5 to 3·0; colour yellow, of various shades; streak shining, opaque; specific gravity 17 to 19.

Gold not unfrequently occurs alloyed with silver, and this compound, where the quantity of silver is considerable, is known by the name of *electrum*. Electrum analysed by Klaproth was found to consist of 64 of gold and 36 of silver, which are almost exactly in the proportions of one equivalent of each metal. Boussingault, who has since examined electrum from various parts of Columbia, found it to consist of very different proportions of the metals, but they were all definite compounds. Gold is separated from the various substances with which it is mixed by the process of amalgamation; this consists in combining it with mercury, and heating the amalgam formed, so as to distil the mercury, which is thus repeatedly used for the same purpose.

Gold is of a fine yellow colour, and is susceptible of a high degree of polish. It is nearly as soft as lead; its specific gravity is 19·3; it is so exceedingly malleable that one grain may be extended over fifty six square inches of surface, and gold leaf is only about $\frac{1}{200000}$ of an inch in thickness; some authors say $\frac{1}{282000}$ of an inch. Gold is also exceedingly ductile; a single grain may be drawn out into 500 feet of wire: in point of tenacity it is inferior to iron, copper, platinum, and silver; a wire 0·787 of a line in diameter is capable of supporting about 150 pounds. Gold suffers no change by exposure to air or moisture, even when heated. It melts at about 2016° Fahr., according to Daniell's pyrometer; when in fusion it appears of a brilliant green colour. It is scarcely at all volatile, and may be long kept in fusion in a furnace without losing weight; but when it is melted by the heat of a lens a plate of silver held over it at some inches distance becomes gilt by its vapour. It contracts more than any other metal on cooling, and crystallises in octohedrons.

We shall now describe the more important compounds of gold. Oxygen and gold unite, but not by direct action; it has indeed been stated that gold may be oxidised by the electric spark in atmospheric air, but this is denied by Berzelius.

Oxide, or Protoxide, of Gold (AuO) is prepared by adding a solution of potash to one of protochloride of gold; a green powder is separated, which is the protoxide in question; it must be washed and dried at a temperature not exceeding 100° Fahr.; if the heat exceed this it is converted into metallic gold and peroxide; indeed, this change is stated by some authors to occur at almost any temperature; it is, at any rate, an extremely unstable compound.

Peroxide, or Teroxide, of Gold (AuO_3) is best obtained, according to Pelletier, by decomposing solution of perchloride of gold by digesting it with a slight excess of magnesia; the peroxide of gold precipitates in combination with the magnesia; after being washed the precipitate is treated with dilute nitric acid, which dissolves the magnesia and a little of the peroxide of gold, but leaves the greater part unacted upon; it is a hydrate, of a bright reddish-yellow colour; but when concentrated nitric acid is used instead of dilute, the oxide is anhydrous, and nearly black. This oxide is decomposed by exposure to daylight, its oxygen being expelled. This oxide is with difficulty soluble in any acid; thus, although sulphuric acid dissolves a small portion, it is precipitated by water. It appears indeed to possess rather the powers of an acid than a base, and has been called *auric acid*, and it combines with potash, soda, and baryta, to form salts, which have been termed *aurates*.

Neither nitrogen nor hydrogen combines with gold.

Chlorine and Gold unite to form two compounds. The perchloride is most readily obtained; it may be formed by treating gold with nascent chlorine, derived from the mutual decomposition of nitric and hydrochloric acids, called *aqua regia*.

Perchloride, or Terchloride, of Gold ($AuCl_3$) gives a yellow-coloured solution, which becomes nearly red by evaporation, owing to concentration and the expulsion of any excess of acid. Its taste is acrid and bitter; with excess of acid this salt crystallises in long needle-form crystals of a bright yellow colour, which are unalterable in a dry atmosphere, but deliquesce in a moist one; on the contrary, when a neutral solution is evaporated until chlorine commences to be evolved, a deep ruby-coloured crystalline mass of perchloride of gold is obtained. Gold is precipitated in the metallic state from the perchloride even by the action of light; hydrogen, charcoal, phosphorus, and many metals, produce a similar effect; so also do the protosulphate of iron, &c. The skin is stained of a purple colour by this solution.

Protochloride of Gold ($AuCl$) is obtained by heating the perchloride to a temperature of about 350° Fahr. in a porcelain vessel. If it be too strongly heated, gold is deposited; it is better therefore to heat it rather less, and to treat the residue with water, which dissolves the perchloride and leaves the protochloride, which is a colourless saline mass, unalterable in the air, but in contact with water gradually changes into metallic gold and perchloride: boiling water decomposes it instantly.

Terbromide of Gold ($AuBr_3$) is procured by dissolving the metal in a mixture of hydrobromic and nitric acids. The solution yields by evaporation a deep red-coloured saline mass; sometimes it yields crystals. This salt has so intense a colour that one part of it tinges 5000 parts of water.

Sulphuret of Gold (AuS_3) is prepared by passing hydrosulphuric acid gas into a solution of perchloride of gold; it is a black powder, which, when heated, readily separates into sulphur and gold. This sulphuret is soluble in the alkalies potash and soda, and prepared in a different mode it is employed in gilding porcelain vessels.

Phosphuret of Gold may be obtained either by directly heating gold-leaf and phosphorus in a tube deprived of air, or by passing phosphuretted hydrogen gas into a solution of chloride of gold. As obtained by the first process it is a gray substance of a metallic lustre; when obtained by the second it is a brownish powder. When heated in the air it is decomposed. Its composition has not been determined.

Teriodide of Gold (AuI_3). Iodine and gold do not act upon each other even when heated together; but when a solution of iodide of potassium is mixed with one of perchloride of gold, yellowish brown iodide of gold is precipitated, which is insoluble in cold water, dissolved by the alkaline solutions, and decomposed by heat.

Having described the principal binary compounds which result from the union of gold with non-metallic elements, we shall mention the more important compounds which it forms with the metals.

Alloys of Gold.—Most metals are susceptible of combining with gold; but it is to be observed that nothing is known of the compounds which it forms with the metals of the alkalies and earths, as potassium, calcium, &c.

Arsenic and Gold.—This alloy is obtained by heating gold-leaf and arsenic; with the application of a gentle heat the vaporised arsenic combines with the gold; it is a very brittle, gray, metallic compound, it is readily decomposed by calcination, and the whole of the arsenic is expelled; $\frac{1}{600}$ of arsenic is sufficient to destroy the malleability of gold without altering its appearance; $\frac{1}{240}$ renders it gray and brittle.

Tellurium and Gold, but mixed also with a considerable portion of lead, occur in combination, constituting three varieties known as—*graphic tellurium, yellow tellurium,* and *black tellurium.*

Antimony and Gold.—According to Hatchett, gold loses its ductility by combining with $\frac{1}{1920}$ of its weight of antimony. It is prepared by fusing the metals together; it is of a pale colour and fine grained; when long calcined in an open crucible the antimony is entirely expelled.

Manganese and Gold.—This alloy is of a pale colour; breaks readily under the hammer, and exhibits a spongy coarse-grained fracture.

Zinc and Gold yield an alloy of a pale greenish colour like brass, and totally devoid of ductility.

Tin and Gold.—Colour very pale whitish-yellow; bends readily when the bar is not more than one-eighth of an inch thick; but when passed between rollers breaks longitudinally into several pieces. The grain of the fracture is fine, inclining to an earthy appearance, and is of a pale yellowish-gray colour.

Iron and Gold form an alloy of a pale yellowish-gray colour; it is very ductile, and may be rolled from the thickness of three-quarters of an inch to that of a guinea.

Nickel and Gold.—This alloy is of a fine brass colour; it immediately breaks under the hammer, with a coarse-grained earthy fracture.

Cobalt and Gold.—A pale yellow alloy mixed with gray; it is brittle, and has a fine-grained earthy fracture.

Copper and Gold combine in all proportions, without altering the colour of the gold; the density is diminished, but the hardness is increased. The alloy employed for ordinary jewellery contains 23·6 per cent. of copper; this tarnishes by use, owing to the oxidisement of the copper; the original colour is restored by treating with ammonia. Copper is used to alloy the gold of coin, in order that it may be rendered sufficiently hard to stand the wear to which it is exposed; the amount of copper is 1 in 12. Its specific gravity is 17·157. Of this alloy, 20 troy pounds are coined into 934 sovereigns and one half-sovereign.

Bismuth and Gold form a very brittle alloy. It is sufficient to alloy gold with $\frac{1}{1920}$ of bismuth to render it brittle. A compound of 8 bismuth and 92 gold is of a pale yellow colour and brittle.

Silver and Gold combine well; the resulting alloys are very ductile. A small quantity of silver renders gold pale; 5 parts to 100 are sufficient for this effect. This compound was used by the ancients, and called by them *electrum*; we have already mentioned the existence of several native alloys of these metals, and that they are always combined in definite proportions.

Lead and Gold.—This alloy is very brittle, even when the lead forms only $\frac{1}{1920}$ of the alloy; even the fumes of lead destroy the ductility of gold.

Mercury and Gold combine with great facility, and yield a white alloy, usually called an *amalgam*, much used in gilding. [GILDING.] On account of the readiness with which these metals unite, mercury is used, as already noticed, for separating gold in the process called amalgamation.

Platinum and Gold combine in all proportions; these alloys are fusible. Platinum readily destroys the colour of the gold; the presence of only 0·02 of platinum is recognised by the extraction of colour.

Salts of Gold, in which the oxide is a base, are obtained with great difficulty; indeed, when the peroxide is dissolved in nitric, acetic, or sulphuric acid, they require to be concentrated, the oxide does not saturate the acids, and the solutions are all decomposed by water.

Salts of gold in which the peroxide acts as an acid do not, except one of them, possess any remarkable properties; this peroxide of gold is soluble in potash and soda, but no very definite or crystallised compounds of them have been formed. Ammoniuret of gold, sometimes called aurate of ammonia, is formed when ammonia is added to a solution of perchloride of gold; water is decomposed, and peroxide of gold precipitated in combination with a portion of the ammonia. This substance is of a yellowish-brown colour; it is to be collected in a filter, washed with a little water, and dried at a temperature below 212°. When this substance is heated it explodes violently, the gold is reduced to the metallic state, water is formed by the union of the oxygen of the oxide of gold with the hydrogen of the ammonia, and azotic gas is given out. It probably consists of two equivalents of ammonia and one equivalent of peroxide of gold; it may, however, possibly be a nitride of gold.

Some of the most permanent salts of gold are the double chlorides: thus the potassio-chloride of gold crystallises in small hexagonal tables; it is, however, quickly efflorescent in the air. The sodio-chloride of gold crystallises in long quadrilateral prisms which are not altered by exposure to the air. When heated it melts in its water of crystallisation, and afterwards loses a little chlorine. It appears to be the most stable of all the salts of gold. It consists of 14·68 parts of chloride of sodium, 76·32 of perchloride of gold, and 9 of water. The chloride of ammonium, the chloride of lithium, barium, &c., form crystalline double salts with the chloride of gold.

There is a compound containing gold which has been long used for giving a red colour to glass, under the name of the *purple powder of Cassius.* According to Berzelius, it is composed of 28·35 of gold, 64 of peroxide of tin, and 7·65 of water. Other chemists have assigned a different constitution to this substance. It is of a fine purple colour, and may be prepared by adding a solution of perchloride of gold to a mixed solution of protochloride and perchloride of tin, or simply by putting tin-foil into a solution of gold.

The general properties of the solutions of gold are, protosulphate of iron precipitates metallic gold from the chloride; protonitrate of mercury gives a black precipitate, and so does the protochloride of tin; but a mixture of the proto- and per-chloride, as already noticed, gives a purple precipitate. Hydrosulphuric acid throws down black sulphuret of gold; ammonia, as already noticed, throws down a yellowish-brown precipitate of fulminating gold, which an excess of the alkali re-dissolves. Many of the metals, phosphorus, and charcoal, precipitate metallic gold, as also do oxalic acid and tartrate of potash, when heated.

GOLD-BEATERS' SKIN. The preparation of the delicate membrane known by this name forms part of an exceedingly dirty and disagreeable class of manufactures called by the French "boyauderie," from the word "boyau," intestine. The strings for violins, harps, and guitars [Catgut Strings], gold-beaters' skin, and some other valuable articles of a membranous character, are made from the intestines of animals—not (except in a few cases) from the whole thickness of the intestine, but from a very thin membrane which covers it either on the interior or the exterior. It is from the large intestine of the ox that gold-beaters' skin is prepared. This intestine is composed of three coats or sheathings; the mucous membrane on the inside, the peritoneal membrane on the outside, and the muscular membrane between them. The peritoneal membrane is the one required for the purpose. In the first place, the intestine is freed from all greasiness by soaking, scraping, and washing; it is then turned inside out, and put into a tub. The tub contains a strong alkaline liquor, in which the intestine is allowed to steep for several hours; and at the expiration of that time the mucous membrane has become so far loosened as to be easily removed. The alkaline liquor employed, called "eau-de-Javelle," removes all trace of fetid odour. The peritoneal membrane is afterwards carefully removed, and stretched out to dry. It is next steeped in a weak solution of potash, and carefully scraped. After this it is stretched out on a frame, with that surface undermost which had adhered to the muscular membrane; another membrane, placed the contrary way uppermost, is laid upon it, and the two are easily made to unite firmly. The membrane is then moistened successively with different liquids, of which one is a solution of alum, one a solution of isinglass, and another a layer of white of egg. Beating, drying, and pressing are also among the processes to which the membrane is subjected; each manufacturer appearing to have his own peculiar mode of proceeding.

A packet of skins properly prepared for gold-beating is rather a costly piece of apparatus; but it will bear a surprising amount of beating without injury. The skins may be used for several months without become thinner or weaker. They acquire, however, by degrees a greasiness of surface which temporarily unfits them for their office; this greasiness is removed by interleaving them with pieces of clean white paper, and hammering them for a considerable time, whereby the greasiness is removed from the skin to the paper.

The unhealthiness of this manufacture has been deemed in France so serious as to engage the attention both of medical men and of the legislature. M. Parent Duchâtelet states that the odour arising from the putrefactive fermentation of the substances used, is more loathsome than any other process incident to manufactures; and that the effect of the exhalation on the health of the inhabitants who lived near the boyauderies was such as to lead the French government, towards the end of the last century, to prevent the boyaudiers from continuing to carry on the manufacture in the faubourg where they had congregated, and where a street was named after them, the Rue de la Boyauderie. They left that spot, and established themselves near Montfauçon; but here they formed a new centre for disease and infection. At length, in or about 1820, the Council of Health offered a prize for the discovery of any mode for separating the peritoneal membrane without subjecting the intestine to the putrefactive action. M. Labarreque obtained the prize, by showing how chlorine could be employed both to fumigate the workshops, and to loosen the membranes one from another without allowing the offensive odour to escape. In 1810 the different manufactories of France were ranged in classes according to the unhealthiness of the employments; and the boyauderies were placed at the head of the list of "Etablissements Insalubres:" they were subjected to rather strict regulations in relation to the position and general arrangements of the buildings; and these rules are still acted on in cases where the new method is not adopted.

This manufacture is also carried on in England. Before the removal of the cattle market from Smithfield to Pentonville, and the pulling down of houses to form Victoria Street, most of the English workers in this disagreeable trade congregated in and near Cow Cross. A *mould*, or group of 800 pieces of gold-beaters' skin, is valued at no less than 10*l.*, for gold-beating purposes.

GOLD BEATING. This is a process whereby gold is brought to the state of very fine leaves, for use in various kinds of gilding. The remarkable ductility of gold—a quality possessed by it in a greater degree than by any other known substance—is here taken advantage of to the fullest extent, as a means of limiting the quantity of this costly material required in gilding. So far is the attenuation carried, that a hundred square inches of nearly pure gold can be purchased for about sixpence.

It is by a combined process of rolling and hammering that the attenuation of the gold is produced. The metal is melted in a small crucible by the heat of a wind furnace; and is cast into an iron ingot-mould, so as to form an oblong flat bar about three quarters of an inch in width, and weighing two ounces: a little borax is used to facilitate the melting of the gold, and the ingot mould is greased on the inside to prevent the adhesion of the gold to it. The ingot, when removed from the mould, is immersed in hot ashes, whereby the gold is both annealed and freed from grease. When cold, it is ready to undergo the process of reduction in thickness, and proportionate extension in length and breadth. Formerly, in France, the ingot was beaten out to the state of a thin riband, by the use of a forging-hammer about three pounds weight; but the French gold-beaters now carry this hammering only to such an extent as to reduce the ingot to the state of a plate about one-sixth of an inch in thickness, and then finish by the use of the rolling, flatting, or laminating mill. In England this forging is dispensed with, and the reduction of the gold to the state of a riband is effected by means of the mill. This mill consists of two rollers made of polished steel, perfectly cylindrical in form, and adjusted with very great nicety; it must so act as to reduce the gold equally in every part, or else the further thinning could not be properly carried on. The milling is continued until the ingot of two ounces is spread out to a surface of 960 square inches, with a thickness of rather more than 1-800th of an inch.

This thin riband of gold is then consigned to the hands of the gold-beater. The hammering does not take place on the gold itself; but thin membranes are interposed between the hammer and the gold. These membranes are of three kinds: an outside covering of common parchment; a set of leaves made of very fine and smooth calf-skin vellum; and another set made of the gold-beaters' skin described in the last article. The riband of gold is cut up into small pieces, each measuring exactly an inch square; and a hundred and fifty of these are interleaved with an equal number of leaves of vellum, about four inches square; each piece of gold being placed on the middle of a leaf of vellum. Over this packet of vellum-leaves is drawn a parchment case, open at both ends; and over this another parchment case at right angles to the former; so that the vellum and gold are enclosed tightly on all sides. The entire packet thus prepared is beaten. This beating is effected on a smooth block of marble, strongly imbedded beneath, and bounded on three sides by a raised ledge of oak wood; the front edge is open, and has a leathern flap attached to it, which serves as a kind of apron for catching fragments of gold that may fall off in the subsequent operations. The hammers employed are very ponderous, weighing about sixteen, twelve, and ten pounds respectively; the heaviest is used first, and the others are brought into use as the gold becomes thinner.

The packet of interleaved vellum and gold is laid on the stone, and the workman beats with regular and heavy blows, on the middle of the upper side; there is a spring or elasticity of the packet which enables the hammer to rise easily after each blow; otherwise the work would be too laborious for any man continuously. The beater turns the packet over from time to time, to equalise the action among the leaves; and he occasionally bends the packet to and fro, to destroy any slight adhesion between the gold and the vellum: he also opens it at intervals, to see how the operation is proceeding. The beating is continued until each little inch-square piece of gold has become expanded nearly to the size of the vellum-leaves; and in order that the whole of the hundred and fifty pieces may be equally acted on, the packet is occasionally opened, and the inner pieces placed near the outside, to receive more action from the hammer.

When this degree of attenuation has been reached, the use of the vellum-leaves ceases, and that of the gold beaters' skin commences. The packet is opened, and each piece of gold, being taken out and placed on a kind of cushion, is cut into four pieces with a peculiar smooth-edged knife.

The pieces of gold, now increased in number from a hundred and fifty to six hundred, are interleaved with an equal number of pieces of the prepared gold-beaters' skin. The packet thus prepared is enclosed in parchment, and beaten in the same way as before, but with a smaller hammer. The pieces of gold become by degrees expanded, until they attain nearly the size of the skin-leaves. The packet is again opened, the leaves of gold are again cut into four each, and the quarters are again interleaved with gold beaters' skin. The cutting is, in this second instance, effected by the smooth edge of a strip of cane, since the thin gold would be liable to adhere to a steel knife. As the pieces of gold, now two thousand four hundred in number, would be too numerous to be beaten in one packet, they are divided into three parcels of eight hundred each, and each packet is interleaved with gold-beaters' skin, enveloped in parchment, and beaten in the same way as before. A third time these leaves expand nearly to the size of the skin-leaves; and by this expansion the necessary degree of thinness is attained. By the three beatings and the two quarterings, the gold is expanded to an area nearly two hundred times greater than it presented when in the form of a riband. The attenuation may be rendered more intelligible by stating that one hundred square feet of the leaf-gold weigh no more than an ounce—a result nearly as surprising as anything presented in the mechanical arts. Gold can be beaten to a much greater degree of thinness than that ordinarily used; but the waste occasioned by broken leaves, and the additional nicety and labour required, more than counterbalance the advantages.

When the last beating is finished, the packet is opened, and the thin leaves of gold removed one by one. The goldbeater makes use of a delicate pair of long pincers, made of white wood, and takes up the fragile leaves of gold one by one. Each leaf is laid down on a cushion, and blown out flat by the breath of the workman: if any of them have been broken or injured in the beating, they are thrown aside, to be remelted for future use; but otherwise each leaf has the ragged edges cut from it, so as to bring it to the size of about three inches and a third square. Small books are prepared, each containing twenty-six leaves of paper about four inches square; both surfaces of every leaf are rubbed with red chalk, to prevent the adhesion of the gold; and twenty-five leaves of gold are placed in each book. In this form the leaf-gold is sold, at fifteen to eighteen pence per book.

The French adopt the same general mode of proceeding as the English gold-beaters, but vary it slightly in detail. The laminated riband is cut into pieces an inch and a half long by an inch wide, and about 1-24th of an inch thick. Twenty-four of these are laid one on another on a smooth slab of steel, and hammered until they are two inches square. Fifty-six of those expanded leaves are made up into a packet, with two leaves of vellum between each. This packet is enclosed in a sheath, and is beaten with a hammer in the same way as in England. Indeed the hammering and quartering, and the use first of vellum and then of gold-beaters' skin, are the same in most of their features as those already described; but the French gold requires more hammering on account of the greater weight and size of the pieces at the commencement of the beating.

Two other metals, silver and copper, have sufficient ductility to be brought into the state of thin leaves by hammering; and both are used to a limited extent in this state in the arts. But these metals would fracture long before such a degree of thinness could be obtained as in the case of gold; and indeed the smaller value of the material renders it less important to economise material in this way: consequently leaf silver and copper are thicker than leaf-gold.

Two inventions of recent date may be briefly noticed here—Lane's ingot, and Bennett's gold-beating machine. In the usual method, described above, an ingot of *alloyed* gold is rolled and beaten; for there is always a little silver or copper mixed with the gold, to render it workable. Mr. Lane's suggestion is, to use a central plate of nearly pure gold, with two plates of alloyed gold on the two surfaces: the alloy to have any tint, or any degree of purity that may be desired. The three plates are heated nearly to fusion, which enables them to combine into one ingot, afterwards rolled and beaten in the usual way. The advantages of this method are assumed to be, that the colour of the leaf is variable at pleasure; and that the pure gold inside affords a highly malleable foundation, which carries the two surface-layers with it. The other novelty, Bennett's machine, is one among many contrivances which have been introduced to hammer the gold by machinery, instead of applying manual labour to it. Most of them have failed, on account of the nice adjustment of force necessary. In Bennett's machine a steam engine, by means of a band, gives motion to a fast-and-loose pulley, which in its turn causes the rotation of a shaft or axis. A cone on the axis, by means of a band, gives motion to another cone on another axis; the band, by minor adjustments is made to shift along the surfaces of the two cones, as a means of regulating the speed of the hammer connected with one of them. Smaller axes, pulleys, bands, wheels, crank-pins, connecting rods, guides, and cross-heads, allow the motion to be brought to bear upon the hammer, which thereupon rises and falls rapidly. The mould, or interleaved group of gold and vellum, or gold and gold-beaters' skin, is placed on an anvil, and is made to shift slowly as a means of equalising the action, after every blow of the hammer. Each upward movement of the hammer sets in motion a system of screws, nuts, axes, pulleys, and tooth-wheels, which cause the mould to shift its position slightly. Notwithstanding the ingenuity displayed in this machine, however, nearly all the leaf-gold manufactured is still beaten by hand.

GOLD-LACE MANUFACTURE. The beautiful substances, gold and silver lace, are produced by the application of a very thin coating of the precious metal to threads of silk. In the original and long-practised method, a stiffened thread is thus produced, applicable to the production of cloth-of-gold and other heavy tissues; but recently-invented processes enable manufacturers to apply gold to perfectly flexible thread. These two varieties may consequently be distinguished as *fibre-plating* and *fibre-gilding*.

Fibre-plating.—This is the process for the well-known gold and silver-lace, largely manufactured both by orientals and by Europeans. The Hindoo gold-lace is thus made. A rod of silver is roughed, and is plated with a leaf or film of gold; the thickness of the gold being to that of the silver in the ratio of 1 to 22. A little moisture and a slight pressure are all that are necessary to hold the gold in its place. The rod is made red-hot in a pan of charcoal; then taken out, hammered, and rubbed with a piece of wood. The rod, about three-quarters of an inch thick and six or eight inches long, is next drawn into wire, by a very rude apparatus, but one which the patient and ingenious Hindoo manages cleverly; it passes successively through many holes in a steel plate, each finer than the one that preceded it. The metal is heated and annealed after each drawing; and this series of drawings and annealings is repeated until the rod is brought down to the thickness of whipcord. Another set of wire-drawers, with greater skill and more delicate fingers, are next employed; they draw the metal through fifteen or twenty holes in succession, until it is reduced to the thickness of the finest hair. The gilt-silver is now too thin to be woven by itself; it would not possess sufficient strength; but it will serve as a covering for silk thread. The fine wire is flattened by a highly-polished steel hammer, working against an equally polished steel anvil; one blow with the hammer suffices to flatten eight or ten wires placed side by side; and the wires unwind from small bobbins or reels as the flattening proceeds. The orange-colour silk is then coated with the wire, by a twisting process, almost wholly without tools, and such as none but the delicate fingers of the Hindoo could perform.

English gold-lace is made in a manner which has recently been described by Mr. Bennoch, in a paper read before the Society of Arts, based on information obtained at the establishment of Messrs. Johnson and Simpson. Here, as in India, there is first the preparation of a rod of silver; then the coating of the silver with gold; then the reduction of the rod to the state of wire; and finally, the twisting of the wire round orange-coloured silk thread. The silver best suited for this purpose is obtained from lead, and is characterised by great tenacity and toughness. It is purchased in the form of a cake, which is melted to a white heat over a charcoal fire, and poured into an ingot mould made of iron or copper. The silver ingot so cast is about two feet long by two inches in diameter. It is brought to a red heat over a charcoal fire, and is beaten with hammers until its length is increased twenty per cent.; its substance being also rendered more dense and compact, by the fibres being then in parallel directions. Then begins the process of reduction. The ingot is drawn through a hole with a steam-engine force of 16-horse power, reducing its diameter and increasing its length. Again and again is this done, ten or twelve times, a smaller die being used each time. The attenuated rod is then thoroughly cleansed, and is ready for the application of the more precious metal. As the gold is applied in the form of leaf, and as all the leaves are of about equal thickness, different qualities of gold-lace are produced by varying the number of gold leaves laid on one over another; the commonest kind, for livery-lace, for the ends of muslins, and for skein-thread exported to India and China, have about ten layers of gold leaf; the best kind, for military purposes and for bullion-embroidery, have thirty; and between these extremes there are many intermediate kinds. The leaves are piled one on another to the requisite number, and such piles are laid side by side till they equal the length of the silver rod; the rod is rolled gently upon them, and the gold slightly adheres, without the intervention of size, water, or any other agent. The rod so overspread is enveloped in paper, tied round with a peculiar kind of cord, and placed in the centre of a heap of lighted charcoal; the paper and cord do not consume until the bar becomes nearly red-hot. The rod, while hot, is burnished with a blood-stone, to expel any air that may remain between the gold and silver, and to increase the closeness of contact of the two metals. When cool, the rod is coated with wax, and is ready for the wire-drawing process. The drawings, heatings, and annealings, are very numerous; for it is necessary to carry on the process of attenuation by minute degrees. So long as steel dies, or perforations in steel plates, were alone used, the silver-gilt rod could not be brought finer than 1000 yards to an ounce of metal; but now, perforated rubies are used for the finer kinds, and an ounce of the metal can be brought to the surprising length of a mile and a quarter. Concerning this invention, Mr. Bennoch said:—"There are not more than three men in London capable of perforating and setting these ruby dies properly; and one man, who works probably not more than three hours a day on the average, has received from one wire-drawing firm as much as 500*l.* or 600*l.* in a single year." Even this wire, finer than any human hair, has so much tenacity, that a piece twelve inches long will bear twelve ounces weight. The wire, after being slightly deepened in tint by passing over a heated cylinder, is flattened in the flatting-mill. This consists of two small steel rollers exquisitely turned and polished; they are brought from Rhenish Prussia, and have had such a large amount of labour and skill bestowed upon them, that they command the enormous price of 120*l.* the pair. The wire, flattened to twice or thrice its original width, and proportionably reduced in thickness, is then twisted upon or around a silken thread, by the aid of bobbins, reels, and a spinning-frame. A beautiful gold thread is thus produced, applicable to the making of gold-lace, embroidery, fringe, &c. Perfectly golden as the exterior is, however, it is surprising how little real gold the thread contains; for, of the whole bulk, nine-tenths is silk, and only one-tenth metal; and, in the average kinds, one-fiftieth part of the metal only is gold, the rest being silver; so that the gold constitutes no more than one five-hundredth part of the substance of the thread. Estimated by one man's labour, it takes 700 hours to reduce the ingot of silver, weighing about 400 ounces, to the finest wire; so extremely numerous are the drawing processes; in the finest kind, the ingot would be elongated to 500 miles of wire. Only 8 ounces of gold are applied to the ingot of 400 ounces; consequently, as a mile and a quarter of the finest silver-gilt wire weighs only one ounce, one ounce of gold suffices to envelope more than 60 miles of such wire.

It has long been believed that the electro-metallurgic process will ultimately be rendered applicable, both to fibre-plating and fibre-gilding, either in the thread or in the fabric. Up to the present time, no such processes have actually succeeded as substitutes for gold-lace made on the mechanical system above described; but we shall presently have to notice one applicable to other purposes.

Silver-lace is made by plating silken thread with a flattened wire of silver. The processes are analogous in principle to those just described, but of course less elaborate and less costly.

Fibre-gilding.—The gilding of fibre has lately occupied a good deal of attention. Chemists and manufacturers have long sought for a mode of coating fibres quickly with gold by some chemical process, as a substitute for the slower and more costly mode of fibre-plating. The French government several years ago offered a prize to the inventor of any such process; but no one earned it by success. Electro-metallurgy then seemed to open a new path, and many ingenious researches were made; but it was found that, although gold could easily be made to attach itself to the thread, the thread was long in drying through being soaked with a solution, and dried without lustre; while the foundation was too soft to admit of burnishing. In short, the brilliancy of gold-lace was not at all imitated by this product.

After many chemical experiments, Mr. Albert Hock succeeded in devising a mechanical contrivance. It is requisite that the silk should be of superior quality, free from knotty nibs and rough places; that the gum should be boiled out of it; and that the silk be dyed to a light orange tint. The silk thread is wound on bobbins; and when about to be gilt, it is transferred to a brass roller, around which it is wound so carefully as to admit neither of interstices nor overlapping. In its passage it passes through a trough containing a glutinous but transparent liquid. Leaf-gold is then laid on the coil of gummed silk, in pieces between three and four inches square; the cylinder being made to rotate partially to aid this application. Leaf after leaf is applied, until all the silk is covered. The gold is then pressed down upon the silk by a piece of cloth or wash-leather fastened to a piece of wood. One side of the silk thread becomes thus gilt. To gild the entire thread, it is transferred to another cylinder: during the passage the gilt side necessarily winds next to the brass on the second cylinder, leaving the ungilt part of the thread exposed, to be treated in the same manner. If it is desired that the woven fabric should present a rich alternation of gold and colours, the silk thread can be dyed of any colour chosen, and only one side or half of it covered with gold. The finished thread is wound upon boards or planchettes, ready to be applied to weaving, lace-making, fringe-making, or any other purpose. The advantages of this gilt fibre over gold lace are—that the material is light and pleasant for garment fabrics; and that, owing to its lightness and perfect flexibility, it can be wound and woven with perfect facility. The disadvantage is, that it cannot be made to present the brilliant and dazzling effect of thread plated with gold. As regards cost, it is said that the finest plated thread, selling at 8*s.* per ounce, measures 550 yards to the ounce; and that gilt thread of equal fineness and length, but weighing only one-third of an ounce, sells at 5*s.* The gilt fibre is dearer than the plated when estimated by weight, but cheaper when estimated by length. Although good gold is necessary for the best work, any combination of gold and silver, gold and copper, silver and copper, or all three, would suffice, if applied in the form of leaf. In some varieties of gauze scarfs the leaf metal used is wholly copper.

Mr. Hock's method of fibre-gilding is not the only one practised. Mr. Green obtained a patent in 1853 for a mode of covering thread with gold, ultramarine, emerald green, and various kinds of coloured powders. He employs metallic powders in the following way:—The thread is first dyed in the usual way; then wound upon a reel; then passed rapidly over a gas-flame to singe off loose filaments; then passed over a roller which dips into a trough of transparent gum; and then between pads of leather to remove any superfluous gum. Thus far prepared, the thread passes over a roller which dips into a trough containing gold powder or any metallic colour in a pulverulent state; by which means it becomes coated with a very thin metallic layer. After this the layer is dried. In one variety of the process the gumming compound is mixed with the metallic powder, instead of being applied previously to the thread. A slight degree of polish is given to the gilt thread by passing it between highly-polished steel rollers.

Other inventors have been at work in the same direction. The Prussian Industrial Association offered, for many years consecutively, a prize of 1000 thalers and a gold medal to any one who should invent an effective mode of gilding silk, on condition that the silk underwent no alteration in other respects. After many unsuccessful competitive attempts, Dr. Kroning of Stolberg gained the prize. The method he invented is applicable either to woven or unwoven silk. The exterior metallic surface is brilliant, and yet the thread remains perfectly flexible. When soiled, the thread or fabric may be washed in soap and water, and pressed lightly before drying.

Electro-gilding, we have said, has not yet been rendered applicable in the gold-lace manufacture. There is one invention, however, by M. Burot, which relates to the gilding of woven stuffs. The textile material to be gilt, whether made of silk or any other fibre, is dipped into a solution of nitrate of silver and ammonia. After remaining in this solution about two hours, it is taken out, and, when dry, exposed to a current of pure hydrogen gas, which reduces the salt, and leaves the silver in a metallic state on the stuff. A silvered surface is thus obtained, which can easily be coated with gold by the electro-metallic process. Gilt and silvered fabrics of considerable beauty are thus produced.

GOLD-LEAF ELECTROSCOPE. [Electricity, Common; Electrometer.]

GOLDEN FLEECE. [Argonauts.]

GOLDEN NUMBER, so called from its having been formerly written in gold letters in the almanacs, is the year of the cycle of nineteen years in which the current year falls. To find it, add one to the year of the Christian era, and divide by nineteen, the remainder is the golden number of the year; but if there be no remainder, then nineteen is the golden number. For the derivation and use of this number, see Periods of Revolution; Metonic Cycle.

GOLDEN RULE, a name given to the rule of three, from its universal use. [Proportion.]

GOMER CHAMBER. [Chamber.]

GO'NDOLA is the name given to the pleasure-boats at Venice, which are very numerous, and serve as a substitute for the coaches and carriages of other cities. The town being built on many little islands, divided by numerous canals, people of every condition are obliged to make frequent use of the gondola, in order to proceed from one district to another. The gondola is shallow, long, and narrow, pointed both at the head and stern, and rowed by either one or two men. It is generally from 25 to 30 feet in length, and 5 feet in width in the middle, where a square cabin is constructed for the use of the passengers. The cabin is furnished with commodious seats, and has glazed windows and black curtains. By a law of the ancient republic, these cabins were uniformly covered with black cloth and hangings, and the gondolas themselves painted black; no distinction of ornaments being allowed, except with regard to the gondolas of foreign ambassadors on the occasion of public ceremonies. The gondolieri, or boatmen, formed an important body or corporation, amounting to several thousands: they were famed for their wit, often licentious, as well as for their skill and honesty. Since the fall of the republic the number of gondolas has greatly diminished, owing to the decrease of the population and its reduced fortunes. Byron, in his 'Beppo,' st. 19 and 20, describes the singularly dark appearance of the gondola,—"just like a coffin clapp'd in a canoe."

GONFALO'NE, GUNTFANO'N, a word of Teutonic origin, derived from *gund*, which in the Frankish and Vandalic dialects meant "war," or "fight," and *fano* or *fahne*, which in German means a "flag" or "standard;" the two together mean a "flag of war." (Wachter, 'Glossarium Germanicum,' art. "Gund;" and Ducange, art. "Guntfano.") Both the French and Italians of the middle ages adopted the word, and the latter corrupted it into "gonfalone," and called the officer whose duty it was to carry the ensign "gonfaloniere." We read of the gonfaloniere of the Holy Church, who was the commander-in-chief of the papal forces. The title of Gonfaloniere di Giustizia was given to a high magistrate of the republic of Florence, appointed by the constitution of 1292. [Dante, in Biog. Div.] The republics of Siena and Lucca had also magistrates called gonfalonieri.

GONG, a Chinese musical instrument of percussion, made of a mixed metal of copper and tin, in form much like the cover of a large culinary caldron, being circular, varying from about 15 to 20 inches in diameter, and having a rim of from 2 to 3 inches in depth. It is struck by a kind of drum-stick, the head of which is of hard leather. The sound or sounds of this instrument—for it produces many jarring ones simultaneously—can hardly be called musical; and in fact the gong, which is very powerful, is only used for the purpose of making sonorous signals, of marking time, and of adding to the clangor of the martial instruments used in war.

GONIO'METER (from two Greek words γωνία, an angle, μέτρον, a measure) is the name of an instrument employed to determine the angles at which the planes of crystals are inclined to each other. [Angle; Plane.] The principle of the common goniometer is simply this. It may easily be shown that if two right lines intersect one another, the opposite angles thus formed will be equal. Hence, regarding the point of intersection as a centre, about which either of those right lines is free to revolve while the other remains fixed, if we suppose one of the edges of a solid bounded by plane surfaces to be applied to that centre, so that the edge may be perpendicular to the plane in which the two right lines are situated, and then suppose the lines to coincide with the two contiguous planes of the solid, it will be evident that the divergence of the lines will be the measure of the inclination of the planes. A graduated arc being now adjusted to the line which we supposed fixed, the position of the other line would indicate the number of degrees at which the planes of the solid were inclined to each other. As this instrument, however, when applied to laminated substances, such as crystals, is incapable of affording results sufficiently accurate to determine the species to which the crystal belongs, in consequence of the frequent irregularity of the fracture and the ordinary minuteness of the planes, we shall, without dwelling longer upon its construction, proceed to describe the more perfect instrument invented by Dr. Wollaston, and called the *reflective goniometer.*

It is well known that a ray of light falling upon a polished plane is reflected at an angle equal to the angle of incidence, and that to an eye situated in the direction of the reflected ray the object from which the ray emanated will appear as much below that plane as it is really above it. If therefore we place one of the planes of a crystal in such a position that the reflection of an object above the plane may appear to coincide with another object beneath, and then turn the crystal until the reflection of the same object above (from the second plane of the crystal) shall again appear to coincide with the same object below, it will readily appear that the arc which the crystal will have described will be the measure of the supplement of the inclination of its two planes, that is, the difference between that inclination and 180°. In turning the crystal the direction of the edge common to its two planes should not be altered, and the rays in both instances should be reflected from that portion of the planes nearest to their common edge, otherwise the observation will be affected by parallax. Such is the principle of Dr. Wollaston's reflective goniometer, by means of which the inclinations of planes whose area is less than the 100,000th part of a square inch may be determined within a minute of a degree, and which is equally effective whether the fracture be even or irregular. The instrument itself consists of a graduated circle mounted upon a horizontal axis, to one extremity of which is attached a moveable pin, having a slit for the purpose of receiving a small brass plate. To this plate the crystal is attached by means of a piece of wax, so that it may project beyond the edge of the plate. The pin (which is provided with a vertical and horizontal movement) is then raised or lowered until the reflection of any convenient object above appears to coincide with some other object beneath. The instrument being thus adjusted, the graduated circle is turned until a similar reflection is obtained from the contiguous side of the crystal. The arc which the circle will then have described will (as was before stated) be equal to the supplement of the inclination of the crystalline planes; but the margin of the circle being graduated in an inverted order, the true inclination is given without further computation, and may be read off by means of the vernier [VERNIER] with considerable accuracy.

GONIOMETRY, the measurement of angles; a name which might be substituted for TRIGONOMETRY, if it were advisable to alter established designations. The latter science, beginning with the measurement of triangles, made all that was known of the analysis of angular magnitude its own peculiar instrument. The various accessions which real goniometry received were therefore considered as additions to trigonometry: so that at this day, under a word which imports measurement of triangles, we have a science which wanders as far from the etymology of its name as geometry does.

GOOD FRIDAY, the name given to the day of our Saviour's Crucifixion. From the earliest ages of Christianity this day, emphatically called Good Friday, has been held as a solemn fast; its appellation of *Good* being applied to express the blessed effects which sprang from that important event.

It is in England only that this day has the appellation of Good: its ancient and appropriate title was Holy Friday, the Friday in Holy Week. Offices called *Tenebræ*, that is, "darkness," are sung on this day, and on its eve and morrow, by those belonging to the Romish faith. The lights are extinguished in reference to the supernatural darkness at our Saviour's Crucifixion, and nearly at the end of the service a solemn silence is observed throughout the church, which is suddenly succeeded by a tremendous noise, in token of the rending of the veil of the Temple, and of the disorder in which the very frame of nature was involved at that momentous event. Good Friday and Christmas Day are the only two days observed in England by a total suspension of business.

Cakes made for the day, called, from the mark impressed upon them, cross-buns, still, even in the metropolis, form the general breakfast on Good Friday; but are not further noticed. In some of the distant counties, such as are not eaten are preserved, to be used as an infallible cure for the faithful throughout the year. The practice of making cross-buns is supposed to have originated simply in the desire of marking on the only food anciently allowed on this solemn fast a symbol of the Crucifixion; but the custom of having some sort of consecrated bread is of great antiquity. The Jews and the Greeks had cakes, Jeremiah (xliv. 19) has "did we make her cakes to worship her;" and the Greeks gave the name of Boun (βουν) to their sacred bread.

Hospinian ('De Orig. Festorum,' fol. 61 b.) tells us that the kings of England had a custom of hallowing rings with much ceremony on Good Friday, the wearers of which would not be afflicted with the falling-sickness.

A sermon used to be preached on the afternoon of this day at Paul's Cross, at which the lord-mayor and aldermen attended in their robes.

Creeping to the Cross on Good Friday was another of the Popish ceremonies formerly practised in England. The ceremonial of it is given by Bishop Percy in the notes to the 'Northumberland Household Book.'

GOOSEBERRY. The *Ribes Grossularia*, indigenous to Britain and some other European regions of cool temperature, and also to the mountains of North America, at an elevation of from 2000 to 3000 feet above the level of the sea, is the origin of the many hundreds of kinds of this wholesome fruit now in cultivation. Its botanical position is described under RIBES, in NAT. HIST. DIV. Its use, as is well known, is more or less within the reach of every one. It is the earliest fruit for culinary preparations; and it may be preserved green for winter use, as also in a ripe state. The plant bears so abundantly that a large quantity may be thinned off for tarts, pies, sauces, &c., in the early part of the season, and still, if done judiciously, a sufficiency left for ripening. The gooseberry will ripen in the extreme northern parts of Britain, near the level of the sea; and in lat. 57°, even at an elevation of 900 feet, it acquires great perfection with regard to flavour. In hot seasons, in the southern counties, the fruit cannot endure full exposure to the direct rays of the sun, which sometimes make it appear as if scalded; under such circumstances evaporation takes place from the whole surface faster than the subjacent tissue can repair the loss: the consequence of which is a complete emptying of the superficial cells of the fruit, which produces death.

The temperature and other circumstances which various species of fruit require in the course of ripening are very important to be known, as they vary in all probability in every different species. In some cases the secretions are formed rapidly; growth is moreover quick from the period of flowering; and a rapidly-increasing temperature, attended by atmospheric moisture, is best suited to the perfection of the fruit: such is the case with the apricot. The fig, on the contrary, demands a long, steady, high temperature, and a dry atmosphere.

In the case of the gooseberry, it appears that the flavour is best where the low temperature of the north brings the fruit more gradually to maturity than it does in the south, where the fruit is in danger of being scorched, and where it ripens far too quickly to acquire the peculiar flavour which it attains in its favourite climate; and a different method of pruning and training ought to be practised accordingly. Thus in the north the branches should be left thin, so as to expose the fruit, and with the same view the spurs should be short. In the south the trees should not be laid so open, and the lateral young shoots, instead of being cut close in, immediately above the fruit-bud at their base, should have two buds left to produce leaves for shading the fruit in summer.

In the manufacturing districts of Lancashire and the adjoining counties the cultivation of the gooseberry has been brought to surprising perfection, at least as regards the size of the fruit: and this chiefly by the manufacturing classes, in consequence of prizes being awarded to successful competitors at the gooseberry-show meetings. Judging from the quality of the varieties grown for competition in this way, it appears that weight is the only qualification required; it is, however, much to be regretted that flavour is not also taken into account. From the neglect of this requisite, many of the fine Lancashire gooseberries are not at all worth cultivation, except on account of their coming to a size sufficiently large for cooking earlier than the smaller. For this purpose those with smooth skins should be avoided, because the skins become tough in the process of cooking.

For flavour, the small, or "Old English" kinds, are far the best, and indeed are the only sorts worth growing; but they do not look well among a dessert. We give below a list of such sorts as are proper for a selection, when flavour is the principal object; and another in which mention is made of the best Lancashire varieties, where flavour and size are in a tolerable degree combined.

Gooseberries are arranged systematically according as their *colours* are *red*, *yellow*, *green*, or *white*; and subdivided with regard to their *surface* being *hispid*, *downy*, or *smooth*.

Small, or Old English, Gooseberries.

Division 1. *Fruit Red:*
* *Surface hispid.*
1. Rough Red.
2. Small Red Globe.
3. Small Dark Rough Red.
4. Scotch Best Jam.
5. Red Champagne.
6. Keen's Seedling.
7. Raspberry.
8. Red Warrington.
9. Rob Roy.
* * * *Surface smooth.*
10. Red Turkey.

Division 2. *Fruit Yellow.*
* *Surface hispid.*
11. Early Sulphur.
12. Yellow Champagne.
13. Hebburn Yellow Aston.
* * *Surface downy.*
14. Rumbullion.
* * * *Surface smooth.*
15. Amber.
16. Yellow Ball.

Division 3. *Fruit Green.*
* *Surface hispid.*
17. Early Green Hairy.
18. Glenton Green.
19. Hebburn Green Prolific.
* * * *Surface smooth.*
20. Pitmaston Green Gage.
21. Green Walnut.

Division 4. *Fruit White.*
* *Surface hispid.*
22 White Crystal.
23. White Champagne.
24. Taylor's Bright Venus.
* * *Surface downy.*
25. Early White.
* * * *Surface smooth.*
26. White Damson.
27. White Honey.
28. Crystal.

Of the above, Nos. 1, 3, 4, 5, 7, are excellent for preserving. No. 14 is the best sort for bottling green. The earliest are Nos, 9, 11, 17, 21, 25, 27; and the latest is No. 8.

Large, or Lancashire, Gooseberries.

Division 1. *Fruit Red.*
* *Surface hispid.*
Leigh's Rifleman.
Lomas's Victory.
Melling's Crown Bob.
Boardman's British Crown.
Bratherton's Huntsman.
* * *Surface downy.*
Berry's Farmer's Glory.
* * * *Surface smooth.*

Farrow's Roaring Lion.
Rider's Scented Lemon.

Division 2. *Fruit Yellow.*
* * * *Surface smooth.*
Dixon's Golden Yellow.

Division 3. *Fruit Green.*
* *Surface hispid.*
Princess Royal.
Hopley's Lord Crewe.
* * *Surface downy.*
Parkinson's Laurel.
Collier's Jolly Angler.
* * * *Surface smooth.*
Massey's Heart of Oak.
Edwards's Jolly Tar.
Large Smooth Green.

Division 4. *Fruit White.*
* *Surface hispid.*
Cleworth's White Lion.
* * *Surface downy.*
Woodward's Whitesmith.
Wellington's Glory.
Saunders's Cheshire Lass.
* * * *Surface smooth.*
Cook's White Eagle.

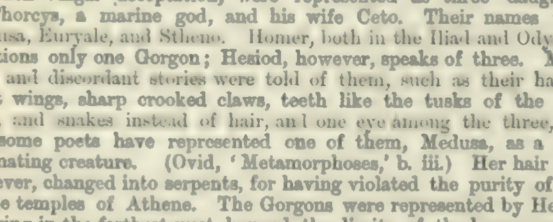
The Pruning of Gooseberries is performed any time during the winter, and before the sap begins to be in motion in the spring. The operation consists in removing all cross laterals, so as to leave the branches as nearly as possible at regular distances, round an open centre, except where the heat of the climate renders it necessary to retain branches in the centre for shade; and the points of these branches, where too extended, or weak, should also be shortened to some well situated bud. Very strong shoots, assuming the character of robbers, should be cut clean out, except such as may be occasionally wanted to supply vacancies. It is however better economy, with regard to the health of the tree, to pinch off the tops of these strong shoots in the summer, and thus prevent their monopolising the sap from the other parts. Suckers, on the same principle, should be prevented from growing at the root.

The branches in all cases should be pruned to a single terminal shoot. In short, the plant should exhibit a regular appearance without any overcrowding in one part and deficiency in another.

GORGE, in fortification, is the name given to that part of any work which lies directly between the interior extremities of its faces or flanks, as between *f* and *g*, *fig.* 1, BASTION.

The prolongations of the magistral lines of two collateral ramparts or walls, till they meet in the interior of any work, as *f* B, *g* B, are called the demi-gorges of that work.

GORGONS, GORGONES, are certain mythological personages, who, in their vulgar acceptation, were represented as three daughters of Phorcys, a marine god, and his wife Ceto. Their names were Medusa, Euryale, and Stheno. Homer, both in the Iliad and Odyssey, mentions only one Gorgon; Hesiod, however, speaks of three. Many wild and discordant stories were told of them, such as their having great wings, sharp crooked claws, teeth like the tusks of the wild boar, and snakes instead of hair, and one eye among the three, and yet some poets have represented one of them, Medusa, as a very fascinating creature. (Ovid, 'Metamorphoses,' b. iii.) Her hair was, however, changed into serpents, for having violated the purity of one of the temples of Athene. The Gorgons were represented by Hesiod as living in the farthest west, beyond the limits of the known world, by Night and the Hesperides; later writers placed them in the unknown regions of Libya. They were said to have had the power of turning into stone all those who gazed at them. At last Perseus, the son of Jupiter and of Danaë, set out, encouraged and assisted by Athene, to encounter the Gorgons, and he conquered them, cut off the head of Medusa, from whose blood, dropping on the ground, the horse Pegasus was engendered. He then gave the head of Medusa to Athene, who fixed it on her ægis or shield, which ever after had the power of turning the beholders into stone. In representations of Athene the head of Medusa frequently occurs. In Greek sculpture of the best period the features of Medusa are extremely beautiful, but with a certain stern and terrible expression, latent however rather than fully evolved. At times, in sculpture, and on coins and gems, the head is almost hideous. A Gorgon's head was the usual ornament on the upper part of the breastplate of a Roman emperor: one is figured on the statue of Hadrian, in the Roman Saloon, British Museum. We give a cut of a Gorgon's head from a terra-cotta frieze in the British Museum, Græco-Roman Basement Room.



Gorgon's head, from a Terra-Cotta in the British Museum.

GOSPEL, derived from two Saxon words of the same meaning as the Greek *evangélion* (εὐαγγέλιον), which signifies "good news," is employed both by the authors of the New Testament and by modern theologians to denote the whole Christian system of religion, and also more particularly the good news of the coming of the Messiah. The books containing an account of the life of Christ were also called gospels by the ecclesiastical writers. Many such gospels were in circulation in the first three centuries, but four only, namely, Matthew, Mark, Luke, and John, were received by the fathers as of divine authority. Several of the other gospels are quoted by the fathers, but not as possessing authority to bind the faith of Christians; and Origen, who appeals to them more than any other writer, expressly says that the church received only four gospels. ('Hom. in Luc.,' i. 1.) We find no quotations from them in the writings of the apostolical fathers, with the exception of a doubtful passage in Irenæus (Lardner's 'Works,' vol. ii. p. 91): none of them appear to have been written till the 2nd century, and several not till the 3rd. The apocryphal gospels which had the widest circulation were, the Gospels according to the Twelve Apostles, the Hebrews or Nazarenes, and the Egyptians. The Gospel according to the Hebrews, which is supposed by some critics to be the same as that according to the Twelve Apostles, was written, in all probability, in the beginning of the 2nd century, in the Syriac language. It appears to have been taken principally from St. Matthew's Gospel, with additions from the other evangelists, and oral tradition. It has been maintained by some critics that this gospel was written by St. Matthew, and that the Greek gospel bearing his name in the New Testament was only a translation of it.

The Apocryphal Gospels which are extant are, 'The Gospel of the Infancy of Christ,' alleged to have been written by Thomas, and by Matthew: it was received as genuine, and is found in the works of St. Jerome, who lived in the 4th century; the 'Gospel of the Birth of Mary;' the 'Protevangelion of James,' and the 'Gospel of Nicodemus.' These were published by Fabricius, in his 'Codex Apocryphus Novi Testamenti,' 2 vols. 8vo., Hamb. 1719-1743, and by Jones, with an English translation, in his 'Method of Settling the Canonical Authority of the New Testament,' 3 vols. 8vo. Lond. 1736-7. The 'Gospel of the Birth of Mary,' the 'Protevangelion,' and the 'Infancy of Christ,' were held in reverence by, and contained some of the principles of, the sect of Gnostics. These gospels appear to have been written with the object of supplying the supposed deficiencies of the canonical gospels. They abound in absurd and improbable tales, principally relating to the early life of Christ, and contain hardly any particulars concerning his public life and ministry. The writings of the fathers give the names of many other gospels, of which the following is an alphabetical list:—Andrew, Apelles, Barnabas, Bartholomew, Basilides, Cerinthus, Ebionites, Encratices, Eve, Jude, Judas Iscariot, Matthias, Marcion, Merinthus, Peter, Philip, Seythianus, Tatian, Thaddæus, Thomas, Valentian. (Jones 'On the Canon,' vol. i., p. 145-150.)

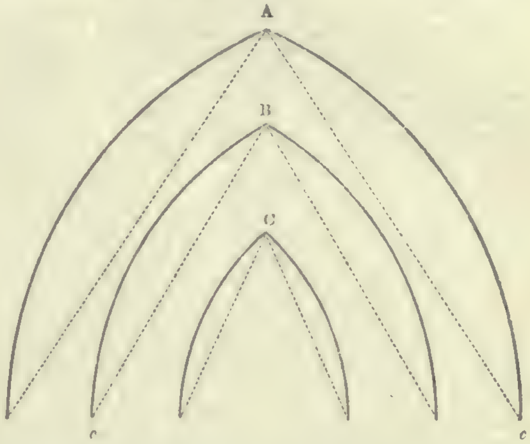
From the many verbal agreements and striking differences in the gospels of Matthew, Mark, and Luke, it has been maintained by many critics that they were derived from an original gospel common to them all, which is supposed to have been drawn up by the disciples who attended the person of Christ; and that this document, which was afterwards lost, is quoted by Clement and Origen under the title of 'The Gospel According to the Twelve Apostles.' This hypothesis was first introduced into this country by Dr. Marsh, in his dissertation 'On the Origin of the first three Gospels,' and has been maintained in Germany by Michaelis, Semler, Lessing, Eichhorn, Gratz, Kuinoel, Bertholdt, and other celebrated critics. An interesting account of this controversy is given in the preface to the English translation of Schleiermacher's 'Critical Essay on the Gospel of St. Luke,' Lond. 1825, 8vo.

GOTHIC ARCHITECTURE. The term Gothic has long been almost universally assigned to that form of architecture which prevailed through a large part of Europe during the middle ages. First applied as a term of reproach, as synonymous in fact with barbarous, and having in itself no special appropriateness, since it was certainly not by the Gothic races, properly so called, that the style was introduced or practised, it is not surprising that writers on Gothic architecture have usually deemed it necessary to enter a more or less formal protest against its use. So generally is the term employed, however, so much has it indeed become incorporated into our language and literature, that it would be hopeless to attempt to replace it by a more fitting one, if even a more fitting one presented itself. But hitherto, at least, no satisfactory substitute has been suggested. The term Christian Architecture at present much in vogue, is palpably a misnomer. What we must continue to call Gothic architecture, was never intended by its originators as in any way antagonistic to what it is now the practice to term Pagan Architecture; nor is there anything essentially Christian in the Gothic style, though it has been chiefly employed on ecclesiastical structures. As Mr. Petit pertinently remarks, had St. Paul succeeded in converting the Athenians, no one can suppose that they would have constructed their churches in this style. In the modern Greek church it has never been employed. Among Protestants it was almost equally unused before the Gothic revival which dates little more than a quarter of a century back: the fall of the true Mediæval Gothic has indeed been by its more ardent admirers attributed to the growth of the Protestant spirit. It cannot be consistently styled Christian, if even Roman Catholicism be taken as the exclusive type of Christianity, for in Rome itself, the very heart and centre of Catholicism, it has notoriously never obtained a footing. The term Christian Architecture is indeed as inaccurate as it is affected and sectarian. Nor can the term Pointed Architecture be admitted as a desirable substitute for Gothic,—though (arched being understood) it is sufficiently significant of its ultimate development. But Gothic architecture is now generally felt to be unduly restricted when it is confined to that branch of it characterised by the pointed arch. Gothic architecture, in fact, comprehends two great branches—Round-Arched Gothic, known as Romanesque, and Pointed-Arched, or that to which the term Gothic is popularly restricted.

The old vexed question of the origin of Gothic architecture, and of the pointed arch, its assumed characteristic, loses much of its significance under the view of its history now gaining general acceptance. Gothic architecture it is seen in reality traces back its pedigree to the architecture of the ancient Romans. As the empire became consolidated, a style of architecture differing more and more from that of Greece was developed. Its distinctive feature was that of the semi-circular arch, as that of Greece was the horizontal beam. Until the utter ruin of Roman nationality and civilisation, the arcuated as opposed to the trabeated mode of construction continued to be practised. When the nations which had formed a part of the Western Empire began to emerge from the gloom which overshadowed them after its fall, the churches they erected were imitations, however poor and feeble, of the basilicas of ancient Rome. Gradually those features of the buildings, whether constructive or ornamental, which go to make up what in the aggregate is called a style, diverged farther and farther from the ancient models, and there was evolved what, from its evidently derived, though ultimately independent character, has been designated the Romanesque. In Italy, and the south of Europe generally, this style continued to retain more resemblance to the original, whilst north and west, where in fact the Germanic races prevailed, it underwent extensive and comparatively rapid changes. Hence some writers would retain the name Romanesque for the architecture of the nations of Roman parentage, assigning that of Round-arched Gothic to the early architecture of the German races. But this ethnological distinction scarcely holds with sufficient tenacity to make it the basis of a separate classification. The simpler and better course seems to be, to regard all the round-arched styles of Mediæval date, as Romanesque; the so-called Lombardic, Norman, &c., being merely national varieties of a normal type. That form, which the divergence from the Roman type assumed in the Eastern Empire, is a wholly distinct thing, and, for the reasons assigned under BYZANTINE ARCHITECTURE, fully entitled to be regarded as a separate and independent style.

Thus, then, we take as the starting point in the history of Gothic architecture the formation of the Romanesque style; but to speak of its full development, its distinctive features, and æsthetic character, and to notice ever so cursorily the phases it assumed in different countries, would swell this article to a very inconvenient length. We shall defer, therefore, a general notice of the round-arched branch of Gothic architecture to the article ROMANESQUE ARCHITECTURE, and a more particular notice of that section of it which we are familiar with in cathedrals and churches of our own country to the heading NORMAN ARCHITECTURE; and here confine our attention to Pointed Gothic Architecture, and especially to English Pointed Gothic.

The question of the origin of pointed architecture, as springing from the invention of the pointed arch, or arch of two centres, was formerly eagerly debated by writers on Gothic architecture. That such discussions were based on an erroneous assumption, we have seen in the article ARCH. The pointed arch was known and used long before its adoption by the Gothic architects. Its employment was forced on them by constructive requirements, either in order to overcome the difficulties arising out of the necessity of vaulting over large and variously formed spaces, as Ware, Whewell, and other able writers think, or, according to the views of Mr. Scott, in order to get rid of the powerful outward thrust of a round arch of large span, or heavily loaded. Be, however, the original inducement to its use what it may, its introduction was the commencement of an entire change in the character of Gothic architecture wherever that style was practised. The pointed arch and arched vaulting became, in fact, the prime principle of Gothic construction. Here, therefore, it may not be improper to explain the different kinds of pointed arch, which are such that the style named from it contains in that respect, owing to its being struck from two centres, a source of variety unknown to any other; for the single centred, or round-headed one, can be varied only by making it more or less than an exact semicircle, in which former case it approaches the horse-shoe curve, and in the latter becomes a segmental or scheme-arch. But arches struck from two centres, and therefore pointed by the two curves meeting each other, may be of various degrees of acuteness, and exhibit great difference as to the proportion which the chord or span of the arch bears to a vertical line drawn from it to the vertex or crown. In the semicircular or one-centred arch the span is invariably equal to double the radius, or line drawn from the centre to the intrados, or curve bounding the aperture; but in the narrow acute lancet-arch, which is extra-centred (that is, is struck from centres on the outside of the arch), the span is less than the radius, and the arch itself consequently narrow and tall, and more or less so in proportion as the distance between the centres is increased or diminished. In the equilateral arch, sometimes distinguished as that characteristic of pure Gothic, the centres coincide with the extremities of the span, which is equal to the radius, so that the chord and the two lines drawn from the centres to the vertex form an equilateral triangle. This species of arch is called by the Italians the *sesto acuto*, because the lines just mentioned are equal to the radius, or one side of a hexagon described within a circle struck by it. When the radius is less than the span,—or, in other words, the centres are on the span itself,—the arch becomes an obtuse-pointed one; and it is hardly necessary to observe, that the arch becomes more obtuse in proportion as the centres are brought nearer each other; for were they to unite, the arch would become a single-centred and semicircular one. All these varieties may occur in the same example; because, if the mouldings be very numerous, and occupy a great space, as is frequently the case in doorways, being all concentric, some of the curves will describe inner-centred or obtuse, others extra-centred or acute arches, as may be perceived by this diagram, which, omitting the intermediate mouldings, will serve to exemplify the several varieties of the two-centred arch above defined.

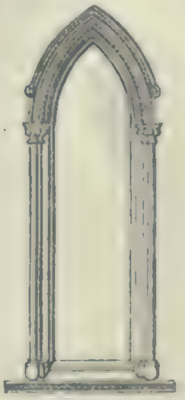


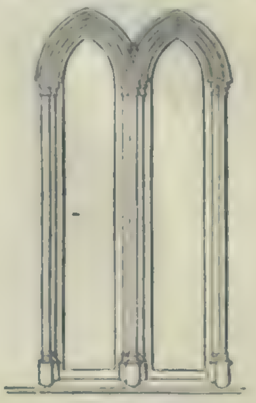
The centres in the intermediate figure (B) being at *c c* respectively, and the line joining *c c* being also the chord or span, B is an equilateral arch: A and C are respectively obtuse and acute arches, the centres in the arch A being on the span, and in C being without it, as above explained. The four-centred arch, so prevalent in our later or Perpendicular Gothic as to be almost characteristic of it, is, on the contrary, struck from two centres on each side, one on the span of the arch, and the other below it, as will afterwards be explained.

Pointed Gothic, as a distinct style, dates from near the close of the 12th century. Mr. Hope, in his 'History of Architecture,' with many of the older Continental as well as English writers on Gothic, considers the pointed style to have originated in Germany, but its birthplace is now more commonly admitted to be France. Some have indeed sought to identify its origin with Suger, the famous church-building abbot of St. Denis; but this is at least doubtful. All that can with safety be asserted is, that at this time France was the great centre of ecclesiastical architecture, and that from her proceeded those new principles which were eagerly adopted by the architects of other countries. But the application of the pointed arch was not a sudden thought. For a long time there had been a growing approximation towards those characteristics of which the pointed arch permitted the full expression. In the quadripartite vaulting of Romanesque crypts we see the first application of that system of vaulting which assumed its full importance in the pointed style; and pointed arches not infrequently occur along with semicircular ones in the later examples of Romanesque, of what has been called the Transition style. But, in fact, Gothic architecture was always in a transition state; and it should be borne in mind when any particular style or form of Gothic is spoken of, that the subdivision into styles, classes, or periods, is merely a matter of convenience. Gothic classification has been dwelt on with very needless emphasis in this country. It has been attempted to define, not only the broad divisions, but the minor subdivisions, and to separate each by a distinct date of origin and termination. Now nothing is more certain than that, during the whole period when Gothic architecture was practised, there was a continuous course of modification, change, or transition, and that in some places the change advanced much farther and more rapidly than at others. The true Gothic architects seem never to have cared much for precedent. Those who had advanced far in constructing a cathedral on the old round-arched type, at the introduction of the pointed arch, without hesitation availed themselves of it in completing their building. If a church of early pointed date had subsequently to be altered or enlarged, they made the new part in the style of their own day, not of that of the builders of the church. Hence we see everywhere a comparatively brief period during which a particular recognised style of Gothic was practised with only such variation as may be readily accounted for by the individuality of the designer, the necessities of the locality, and the like; but, then, on both sides of that middle period there is an admixture more or less marked of the characteristics of the style which is passing away, or of that which is as yet only thus foreshadowed. Thus, with the period before us, we may see in our own country pointed Gothic arches, and other traces of the coming style, very instructively intermingled with Norman round arches, &c., in parts of Canterbury Cathedral, the east end of Chichester and the choir of Lincoln cathedrals, parts of the fine abbey churches of St. Albans, Glastonbury, and Malmesbury, and in several other of our cathedrals and larger parish churches; and in France in Chartres Cathedral, the abbey of Fontenay, the churches of Pontigny, St. Germer, and many others, and notably in those of Central France. And in speaking of these French churches, it deserves to be noticed, that this transitional style, in which the characteristics of the Romanesque and the Pointed are so intimately blended, did, in fact, continue its existence through Central France, Lorraine, and elsewhere almost to the end of the 13th century,—in other words, during nearly the whole range of the early pointed style. (De Caumont, 'Bulletin Monumental,' and 'Architecture Réligieuse.')

The nomenclature and chronology of the styles of pointed Gothic generally accepted in this country, are those proposed by the late Mr. Rickman in his 'Attempt to Discriminate the Styles of Architecture in England.' Taking the Anglo-Saxon and Norman as pre-Gothic divisions, he reduced the classes of Gothic proper to three: *Early English*, which prevailed from the end of the reign of Henry II. to the end of that of Edward I., or from 1189 to 1307; *Decorated English*, from the beginning of the reign of Richard I. to the end of that of Edward III., or from 1307 to 1377: and *Perpendicular English*, from the beginning of the reign of Richard II. to the end of that of Henry VIII., or from 1377 to 1546. His arrangement was doubtless an improvement, because a simplification of those which preceded it; but though seemingly specific it is really deficient both in precision and accuracy. The terms Early English, Decorated, and Perpendicular, are formed on no common principle. If Early English were a good title, some other terms referring to time should have been combined for the later periods. Decorated is in itself apt enough for the second style by way of comparison with the style which preceded it, but most unapt as compared with its successor. So, again, Perpendicular seems sufficiently distinctive when the window tracery and panelling of the style are regarded, but it is characteristic of little beyond those features: the extension of the term to the end of the reign of Henry VIII. is generally given up. Later writers (as Mr. Sharpe) have proposed a geometrical arrangement:—*Lancet* (1190—1245), *Geometrical* (1245—1315), *Curvilinear* (1315—1360), *Rectilinear* (1360—1550); or (as Messrs. Garbett and Fergusson) a chronological one:—Plantagenet, Edwardian, Tudor; which have at least the merit of defining by sharply marked outlines. Another classification has however been proposed, which has the opposite merit of being less rigid in its boundaries, while it is not less explicit in expression. It is that of ***First Pointed, Second*** (or ***Middle***) ***Pointed***, and ***Third Pointed***; corresponding generally to the Early English, Decorated, and Perpendicular of Rickman. This, some of the more systematic of its partisans have again subdivided and formularised; but if it be taken as a mere convenient form of expression, it will, we believe, be found superior for all practical purposes to any other. Continental writers very generally speak of the Gothic of the 13th, 14th, or 15th century; and as it fortunately happens that the styles prevalent during those centuries are well marked varieties, this mode of speech is a very good one. But in France at least (and with French Gothic our own is nearly cognate as well as synchronous) the terms *Ogival Primitif*, *Ogival Secondaire*, and *Ogival Tertiaire*, are recognised definitions; and with them our own First, Second, and Third Pointed Gothic would exactly correspond, if we understood that those terms were merely convenient expressions for the Gothic of the 13th, 14th, and 15th centuries respectively. In fact, whatever classification be adopted, there seems a general inclination to make these centuries its chronological basis. Without therefore venturing to discard Rickman's terminology, we may now say that Early English, or First Pointed, may be taken to stand for the architecture of the 13th century; Decorated, or Second Pointed, for that of the 14th; and Perpendicular, or Third Pointed, for that of the 15th: it being clearly understood that neither style was really circumscribed within strict dates.

The Early English, or First Pointed style, had arrived at its full development in the early part of the 13th century. Characteristic contemporaneous examples in England and France are the cathedrals of Salisbury and Amiens, commenced respectively about the year 1219. In both of these the round arch and massive columns of the preceding style have quite disappeared. The buildings are lighter, loftier, more graceful in their proportions, more beautiful as a whole, more finished in the details, distinguished by vertical rather than horizontal lines, and exhibiting a great advance in constructive power. In them, as Mr. Fergusson points out, are shown what continued to be characteristic points of difference between English and French cathedrals: the English showing greater length in proportion to width, less altitude, square instead of apsidal terminations, and more restraint in the ornamental details. Turning to the broad distinctive forms and details of the style as shown in English buildings, we observe that at first the arch was exceedingly acute, and employed chiefly where small span was required, as in windows, which at first consisted of a single aperture, then of two, either distinct, with a narrow space or pier between them, or combined together by means of a central pillar. This led to similar grouping of three apertures, the centre one of which rose higher than the others, and also to the practice of enclosing them within a larger arch, the space between which and the lesser ones was filled up with a circular arch, whereby the whole acquired not only greater variety, but that architectural distinctness and completeness of form in which the earlier kind of double-window was deficient on account of its outline sinking instead of rising in the centre, and it looking merely like two arches belonging to an extensive range. These gradations in the compositions will be clearly understood from the subjoined figures, the first and third of which are specimens from York Cathedral, the second from Winchester, and the fourth from Westminster Abbey: the mode shown in the last evidently led the way to that of decorating the window-head, by dividing it into smaller and more varied compartments of ornamental panelling, which, whether perforated or not, is known by the general term of tracery, and constitutes a species of embellishment predominating in all the varieties of Pointed Gothic, and likewise in all the different national schools of it.


York.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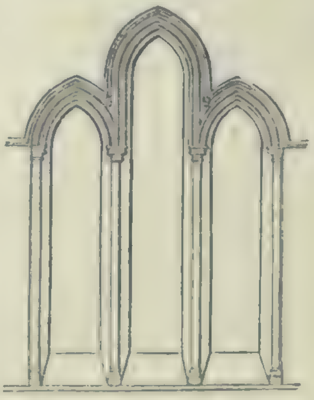
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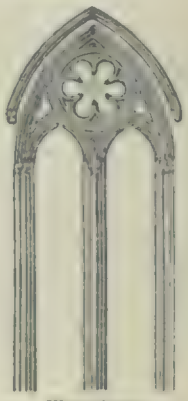

Westminster.

In the first class of our own First Pointed, or Early English, the openings of the windows are lancet-headed, and not only narrow but tall; that is, the part below the spring of the arch is very long in proportion to its width, a circumstance totally independent of the form of the arch itself, and therefore affording the greater scope for variety. In fact, we behold a striking difference in respect to proportions exemplified in the doorways of the same period; for although similar as to general character, and frequently, like the later double-window above represented, consisting of two arches divided by a central pillar, either single or clustered, with a circular compartment above them in the larger arch-head, the height from the ground to the springing of the arch is sometimes even much less than the width of the whole design, and not much more than double that of the smaller arches. The receding sides, or splays, of such doorways were as deep as those in the Norman style, and enriched with columns; and the dripstone, or hood moulding (for it is variously termed, and is the only moulding projecting from the wall, as all the others receded within its surface), not unfrequently rested upon carved heads. Instead of being placed upon pillars or cylindric piers, as in the Norman style, the pier-arches (so called in order to distinguish them from arches introduced in walls), which are mostly lancet ones, are placed upon piers with shafts attached to them, so as to give the whole a clustering form; but there is so much variety, both as to plan and the enrichment of capitals and other details, as to render it impossible to enter into particulars without numerous explanatory drawings from different examples. The buttresses have greater projection than the parts which appear to answer to them in Norman architecture. They are also narrower, and some of them are divided into two or more stages by set-offs, or horizontal splays, reducing the projection from the wall at every stage. Flying buttresses were now first introduced [BUTTRESS]. Gargoyles also first appeared at this period both in France and England [GARGOYLE], and were a part of the system now fully recognised of making even the inferior accessory features ornamental. The columns frequently consisted of a thick central pier surrounded by slender detached shafts; but clustered columns introduced during the transition period became general. Capitals were generally bell-shaped; with a round or octagonal abacus. The foliage on capitals and elsewhere was frequently a close imitation of local plants and flowers; and floral ornamentation became much more general. The mouldings are in the earlier examples often Norman or transitional in character, in the later Decorated; but those distinctive of the style are round or pointed, with very deep hollows and variously filleted. (See examples in Paley's 'Gothic Mouldings.') String-courses and labels were much more extensive and continuous than in the previous style. The mode of wall ornament called diapering was now first employed. The statuary and carving generally became much more artistic during the continuance of this style; and indeed nothing can in its way well exceed the richness and beauty of that of the east front of Ely, and the west front of Wells, cathedrals.

The use of groined vaults, pointed arched windows, and flying buttresses permitted the construction of walls of a less massive character than those of Norman date, and the carrying them up to a greater height. Spires were likewise built of a much greater altitude, and many of them are of an exceedingly elegant outline. Roofs were generally acute in pitch; and of open wood-work as well as stone vaulted. Parapets were generally plain. The characteristics of the painted glass of the windows of this and the two succeeding styles e indicated elsewhere. [GLASS PAINTING.]

Choir, Salisbury Cathedral.

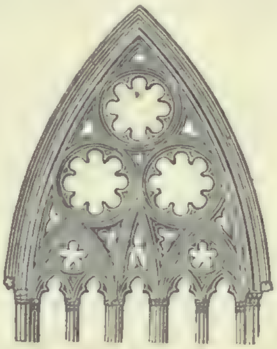
The most perfect English example of the First Pointed style is Salisbury Cathedral, which was begun by Bishop Poore about 1219, and finished about 1260—being therefore what is so rarely seen, a cathedral completed wholly in one style, and uniform in character throughout. Lincoln Cathedral, though not throughout First Pointed, is a noble example of the style. The nave and transept of Westminster Abbey afford another important example, the more noteworthy because possessing even more of the French than the English First Pointed character. Ely, Peterborough, Wells and Worcester, the east end of Winchester, the lady chapel Hereford, and York Minster, especially the unrivalled five-sister lancet windows. Ripon and Beverley minster, and the Temple church may be cited as among the important examples of the style; but the list might be greatly extended, especially by the addition of numerous parish churches.

In France, characteristic examples are the cathedrals of Sens, Amiens, Reims, Notre Dame de Paris, St. Dénis, Bayeux, Chartres (the nave); the abbey of Fontenay; the Ste. Chapelle at Paris; the churches of Pontigny, Trévière, Calvados, St. Germer, &c. Germany possesses a very interesting and beautiful specimen of the same style and period in the church of St. Elizabeth at Marburg, which is nearly contemporary with the cathedrals of Salisbury and Amiens, having been constructed between the years 1235 and 1283. It is fully described by Moller in his work on German-Gothic architecture, where it is illustrated by eighteen plates; and an elevation of its west front forms the frontispiece to the translation of Moller's text by Mr. W. H. Leeds. The cathedral of Magdeburg, another very fine example, shows more decidedly the influence of the French taste, an influence which strongly affected the course of German-Gothic. The choir of Cologne Cathedral (about 1270-1322) belongs to this style. Freyburg (1283-1330) is an example of the tendency of German-Gothic towards extravagance of ornamentation, with, in the open-work spire, &c., excessive lightness. The nave of Strasburg cathedral, Altenburg, and many other German churches, are of this period.

The transition from the First Pointed, or Early English, to the Second Pointed, or Decorated style, was made by almost imperceptible steps. The dividing line is variously drawn between 1270 and 1307: as for its termination, some one or other year somewhat anterior to 1379 is usually assigned: but as we have said, it is safer, and sufficiently precise, to regard the Second Pointed as the style of the 14th century, remembering that towards the close of that century some important buildings of unquestionably Third Pointed character were erected.

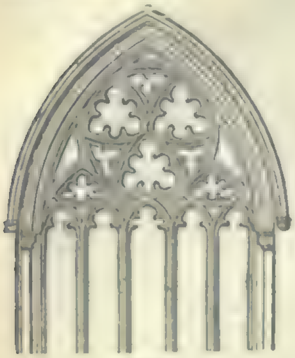
As compared with those of the First Pointed, the churches of this period are distinguished by much greater richness of ornamentation, but in its development English architects seem to have been restrained by marked sobriety of taste as compared with those of France and Germany. In England Gothic architecture must be regarded as having reached its most perfect form during this period: the succeeding period was one of decline. In France and Germany there was already some loss of purity, though the full flow of extravagance and debasement did not occur till the next century. As in the previous style, the windows and vaulting are the distinguishing features. There was little difference in the arrangements of the buildings, except perhaps that symbolism was more regarded. The vaulting is more subdivided into cells than that of the previous period, by the addition of intermediate ribs intersecting each other so as to produce a kind of tracery consisting of stars and other figures whereby much variety and richness are obtained. Richly carved bosses occur also at the intersections of the ribs. Some of these groined roofs are very beautiful; those of choirs are generally more elaborate than those of naves. Of the open wooden roofs of this period, not many examples remain.

Of windows a no less instructive than beautiful transition illustration is afforded by those of York Chapter-house, where we distinctly behold the progress to more complex geometrical tracery. The arch of the window is still of the lancet form, and highly pointed, being extracentred about two-thirds of its span; and the increased degree of enrichment is produced, not by the introduction of new elements, but by repeating and combining those previously in use. Thus the foliated or cusped circle continued to be the chief member decorating the head of the window, being merely tripled in number, an arrangement which accords beautifully with the triangular outline of the space so occupied; at the same time that these circular divisions contrast agreeably with the acute form of the arch, and soften its asperity. In like manner the multiplied divisions in the lower part of the window are produced by merely putting together two arched compartments with circles in their heads, similar to the example already given from Westminster, with a narrower one between them; thus forming the whole lower space into five narrow compartments, each of which has its own arch. In these lesser arches, which are simply cusped, and so far differ from those in the first example, we see the commencement of trefoil and cinquefoil ones; while in their shafts we plainly recognise mullions, which were afterwards of general application, either of uniform dimensions, or, in larger windows, consisting of principal and secondary ones. When the arch became equilateral, or nearly so, the tracery also assumed a different character, becoming of that kind which is called geometrical, and consisting of more varied forms and patterns, produced by circles, portions of circles, and other curves, enriched with cusps, dividing the spaces into foils. Of such windows we give examples from one at Exeter, and another at Kirton Church, Lincolnshire. This distinction between tracery by geometrical figures (circles, triangles, &c.) as shown in the first of these examples, and that formed by flowing curves as in the second, is observed throughout the window tracery of the earlier and later parts of the Second Pointed style: hence it has been proposed to subdivide it into the Geometrical and Curvilinear, or Geometrical and

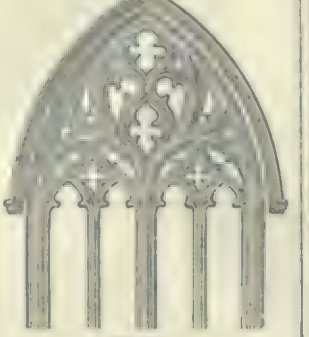


From York Chapter-house.

Complete Middle Pointed; the dividing line being variously fixed about 1315 and 1330.



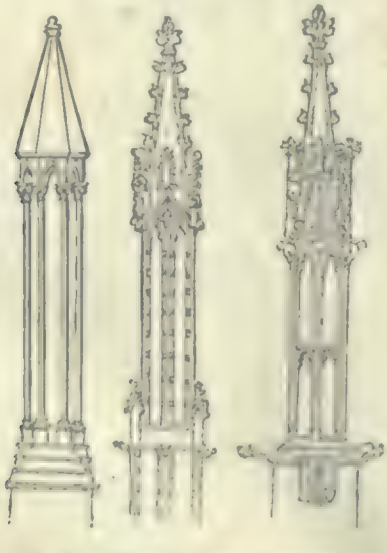
Exeter.



Kirton.

In the first of the examples given above, the pattern is formed chiefly by a single large circle subdivided into three spherical triangles sixfoiled, and three lesser ones trefoiled; to which minutiæ we call attention in order that the reader may be led to examine the figure attentively, and thereby learn, without further explanation, what is meant by those terms, and by *foils* and *cusps* generally. He will here further observe that small shafts and capitals have given way to mullions as dividing the lights, although retained at the sides of the window. The other example differs from the one just spoken of, not only in its tracery, which is more playful and flowing, but in having two orders of mullions, that in the centre, or the principal mullion, being thicker, and composed of more mouldings than the secondary ones. It deserves also to be remarked, that here the number of the open spaces, or lights, as they are termed, is even, and that of the mullions uneven; whereas in the other and the preceding figure the lights are uneven, and the mullions even in number; a circumstance quite independent of style, since either mode is followed according as it best suits the design for, and principal divisions of, the window-head. Of what is called geometrical tracery numerous specimens occur in the rich west front of York Cathedral, finished about 1330.

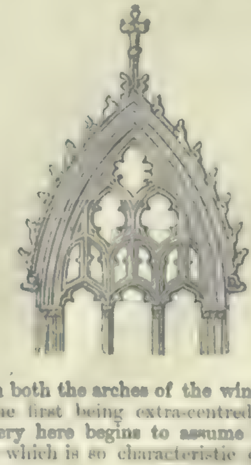
As mullions began to be substituted for pillars or shafts in windows, so too, both in the splays of doorways and in arch piers, columns began to be incorporated with the main pier, or splay itself; and in smaller doorways the arch mouldings are frequently continued down vertically, without any indication of capital, or impost to the arches, and die away, as it is termed, into a sloping surface, at a short distance from the ground. The external projecting mouldings of the arch, called by some hood-mouldings, by others weather-mouldings, or dripstone, as serving to throw off the droppings of rain, usually rest on corbels cut into the forms of heads. In many instances these hood-mouldings, both of doors and windows, are surmounted by other mouldings, forming a kind of gable, distinguished by the name of canopy. These canopies are generally enriched with crockets, small leaf-like ornaments, placed at intervals on the outer edge, which were first introduced, but used much more sparingly during the First Pointed period. The pediment heads to the different stages of buttresses are often similarly decorated. In conformity with the rest, greater ornament was likewise bestowed upon pinnacles, as will be seen on comparing a specimen of First Pointed character, from Wells Cathedral, with two others belonging to the Second Pointed style, the first from St. Mary's, Oxford, the other from York.

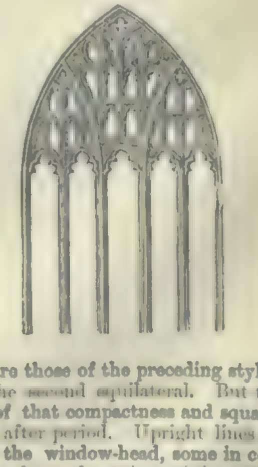


Doorways of the Second Pointed style are in the more important buildings often very richly sculptured. The shafts are thin, the capitals have the characteristic freely carved foliage; the jambs are finished with crocketed canopies, and small statues occupy narrow niches; the mouldings are enriched with ball flowers, foliage, &c.; the weather-moulding is supported by corbels carved as heads, or by bosses of foliage, and is terminated by a finial; and where the opening is wide it is sometimes divided by clustered shafts, as at the chapter house of York minster. Some of the earlier doorways are narrow, and resemble those of the First Pointed period, but are less deeply recessed,—a distinction maintained throughout the period. Stone porches are not infrequent; they are often large, richly sculptured, and in some instances have a room over them. The buttresses of this style are much more varied than in the First Pointed; flying buttresses are frequent, and of excellent outline and proportions. Parapets are either pierced or panelled, and sometimes embattled. Columns are in the plainer churches cylindrical or octagonal; but in those of a superior class they consist of clustered half or three-quarter cylindrical attached shafts, sometimes set lozenge-wise on the plan. Their bases are somewhat peculiar; in plan they sometimes differ from the shafts, and they are formed by a series of mouldings. The capitals usually, but not invariably, agree with the form of the shafts, and have fillet ogee or other cap-mouldings. In larger churches the capitals are enriched with foliage, sharply and often admirably carved, and sometimes seemingly direct from nature. The abacus is less prominent than in First Pointed capitals. Mouldings are very varied, and introduced with great effect, but it is quite impossible to particularise them. They will be found amply described and illustrated in Mr. Paley's 'Gothic Mouldings,' and other works which treat of the details of Gothic architecture. As a useful generalisation,—not to be received as an invariable law,—we may quote Mr. Paley's broad discrimination of the mouldings of the three periods: "It may be stated as a principle, that First Pointed mouldings exhibit a predominance of concave, Middle Pointed of convex, Third Pointed of sharp-edged members." As characteristic examples of this style may be mentioned the choir of Lincoln cathedral (1324); the nave and the west front of York Minster (completed 1330); the lady chapel and choir of Ely; parts of Lichfield, Bristol, Worcester, Winchester, Norwich, Wells, Canterbury, and Carlisle cathedrals; the magnificent parish churches of Grantham, Boston, and Heckington, in Lincolnshire; Hingham, Norfolk; Howden, Yorkshire; Dorchester; Adderbury, Stanton-Harcourt, and Bloxham, Oxfordshire; Trumpington, Cambridgeshire; several of the churches of Northamptonshire; and many others to be found in every part of the country.

In France, as in England, the Gothic of the 14th century (Ogival secondaire) is distinguished from that of the 13th chiefly by an increase of sculptural ornamentation, the introduction of more elaborate window tracery, greater lightness and venturesomeness of construction, and altogether a greater solicitude for splendour of effect. But whilst in England this tendency was kept in check by sound judgment and great sobriety of taste, in France the architects permitted themselves to run into excess; and, despite their surpassing splendour and picturesqueness, even their best buildings exhibit a decline from the high standard of the preceding century. Among the more remarkable examples of this period are the churches of St. Ouen, Rouen, and St. Laurent au Puy, and parts of the cathedrals of Rouen, Tours, Amiens, Paris, Bayeux, Poitiers, Nevers, Narbonne, &c.

In order to exhibit the progress from this to the Third Pointed style, we give two transition specimens of windows from York choir, the first decidedly of a transition character.

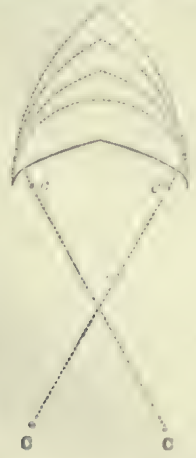




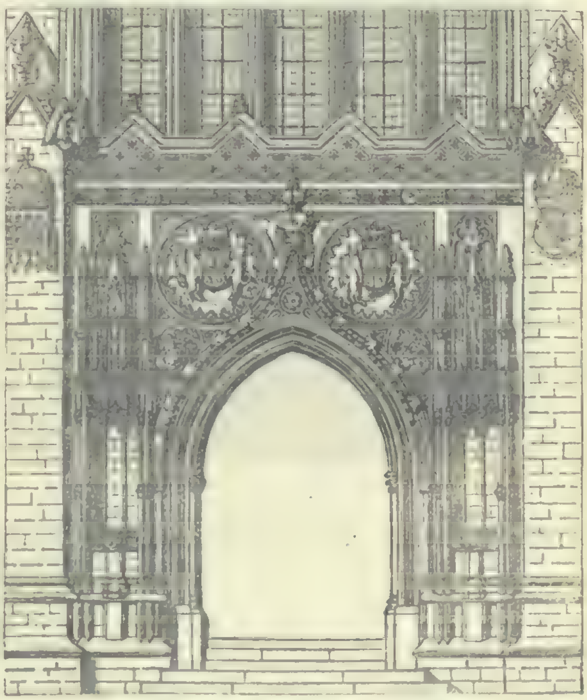
In both the arches of the windows are those of the preceding styles, in the first being extra-centred, in the second equilateral. But the tracery here begins to assume some of that compactness and squareness which is so characteristic of the after period. Upright lines or shorter mullions are introduced into the window-head, some in continuation of those below, others rising from the points of the arches which form the heads of the lower compartments; so that if we wished to express this circumstance by a single term we might employ the epithet *super-mullioned*, as indicating that the upper divisions of the windows have mullions rising from the arches of the lower ones. These two examples will further be useful, the first as supplying an example of *crockets* on the outer arch-moulding, and of a *finial* on its apex; the other as an instance in point, as respects what we have said of very acute arches being included in the tracery to windows whose arches are equilateral, or even much lower; for those which form the heads of the two compartments, each comprising two lights on either side of the centre one, are highly pointed, being extra-centred, and their height equal to $1\frac{2}{3}$ their span.

Of the Third Pointed, or Perpendicular, style, which may for convenience' sake be dated from 1400, and considered that of the 15th century, we must repeat that although the name Perpendicular, first bestowed on it by Rickman, and since very commonly adopted, appears to be tolerably correct in some respects, it is objectionable, and indeed misleading, in others; because, if "the mullions of windows and the ornamental panellings run in perpendicular lines," it is no less obvious that the numerous transoms, square-headed labels to doorways, and ornamental string-courses and cornices, produce as many horizontal ones; consequently Horizontal would be an equally appropriate term; perhaps even the more appropriate of the two, since the mullions thus crossed by transoms do not exhibit that prevalence of perpendicular lines which mullions alone, or slender columns do. The same may be said in regard to labelled doorways, &c., where the pointed character produced by the arch in a great measure loses itself, and is exchanged for that marked by squareness of outline. Nay, in the later examples, the very form of the arch itself shows a tendency to horizontality, by becoming so flattened that the height is sometimes less than one-fourth of the span (whereas in the equilateral arch it exceeds that measure).

Windows of this period are of two classes, two or four-centred: the former belong to the earlier, the others to the later half of the continuance of the style. What at once distinguishes Third Pointed windows from those of the earlier styles, is the vertical bearing of the mullions. In First and Second Pointed examples the mullions diverge in the head of the windows into curves or flowing lines: in the Third Pointed they are carried straight up till they cut the enclosing arch, while smaller divergent and upright mullions and transoms divide the head into smaller arched and panel-like compartments. In some of the richer examples the transoms are *embattled*, or indented by being cut into small battlements. As to the variety displayed in the tracery of the windows, it is quite impossible to describe it, since almost every specimen exhibits a different pattern; its general character may however be understood from the second of the examples above given from York Cathedral. The depressed or four-centred arch is so characteristic of the latter portion of this period, that a few words may be well devoted to a more particular notice of it. By the annexed diagram it will be seen that the superior centres, *c c*, for the shorter radii describing the two quadrants at the spring of the arch, are upon the span-line itself; and the two inferior centres, C C, whose radii are in continuation of the others, describe the remaining curves meeting at the vertex of the arch. This compound form admits of great diversity, according to the proportion the shorter and longer radii bear to each other, or in other words, according as the centres are fixed. In order to exhibit at the same time a comparison of this kind of arch, both with the semicircular and the varieties of the two-centred one, we have enclosed it within dotted lines, representing the others in succession above it, by which it will be apparent that if the span be the same, the extra-centred or lancet arch will be the highest, next to that the other two-centred arches, then the semicircular one, and lastly the compound or four-centred arch. But if, on the contrary, they were all made equal in height, the order of precedency would then be reversed, for the four-centred one would be the widest, and the lancet the narrowest, as has already been partially exemplified in a preceding diagram. Examples of this compound arch occur in French buildings of the latter part of the 15th century, but so rarely that it may be regarded as almost peculiar to England. From its frequent occurrence in the buildings of the close of the 15th and first half of the 16th century, it is commonly known as the Tudor arch.



Of Doorways the outline became square, owing to the arch being inclosed within mouldings forming what is called a *label*, which generally terminated at the spring of the arch, where it either rested upon corbels in the form of shields or heads, or was else bent and returned horizontally for about double the breadth of the other mouldings. The triangular spaces or *spandrels* thus formed between the curved mouldings of the arch and the square ones of the label are mostly filled up with quatrefoil circles or other decoration. In the larger and richer kind of doorways, as in the porch of King's College Chapel, Cambridge, the spandrels are greatly enlarged by the head of the square panel or compartment in which the arch is placed being carried up much higher. In this example there is an ogee canopy formed by what are called mouldings of *contrary flexure;* and this is crocketed and surmounted by a finial. Although this specimen, which has been selected as a beautiful instance of the Third Pointed style, does not exhibit the four-centred, or compound arch, it should be remarked that the latter characterises the other parts of the edifice. In the architraves or mouldings along the sides of doors and windows there are generally one or more large hollows, which may be taken as one of the marks of this style.

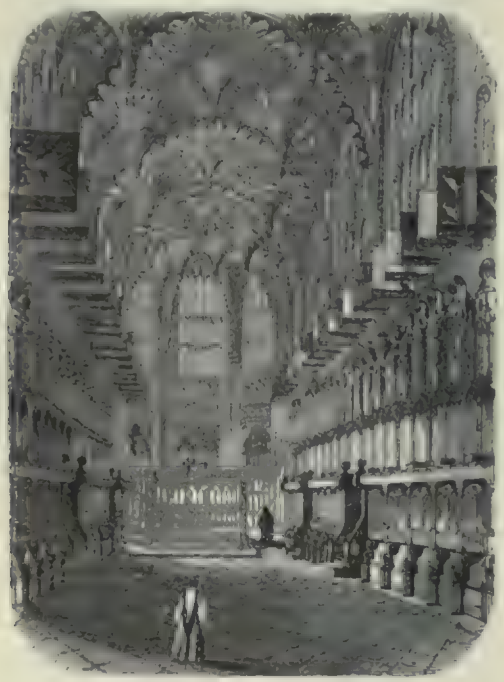


Doorway, King's College Chapel, Cambridge.

Although they have not labels, both windows and pier arches are not unfrequently treated somewhat similarly, being placed within square-headed compartments, whose spandrels are filled up with tracery resembling that of the window; which practice, no doubt, afterwards led to that of square-headed windows, by perforating the whole compartment, and making the spandrels part of the window itself. Windows placed within compartments, with spandrels of blank tracery, may be seen in the clerestory of Henry VII.'s chapel.

Hitherto we have spoken chiefly of arches and windows, but we must now briefly advert to the roof, at least to one species of vaulting used for it, peculiar to the richer examples of this style, we mean that consisting of *fan-tracery*, so called from the numerous small ribs or mouldings spreading out from the spring of the groining as from a stem, and radiating so as to describe a semicircle, the fan on one side meeting that on the other, in the centre of the vaulting; whereby a spandrel with four convex curves for its sides is left between two opposite pairs, and this space is either filled with tracery arranged so as to form a circle, or else is occupied by what is called a *fan-pendent*, similar to the other fans, except that its base on the ceiling is an entire circle instead of a semicircle. Of fan-groining with enriched spandrels only, the cloisters of St. Stephen's chapel, Westminster, offered a beautiful example; and of that with pendents, the chapels of King's College, Cambridge, and Henry VII., Westminster. The two structures just mentioned and St. George's chapel, Windsor, are in every respect perfect examples of this style, being of uniform design throughout, without intermixture of any other. Examples of the plainer vaulted roofs occur in the nave of Winchester cathedral, the nave and choir of Norwich, the choirs of Gloucester and Oxford, and the

Beauchamp chapel, Warwick. The open wooden roofs of this period are also characteristic, and sometimes extremely fine: that of Westminster Hall is one of the most striking. Brandon's 'Open Timber Roofs of the Middle Ages,' 4to, 1849, supplies ample particulars and illustrations of them. Usually the roofs of this period are of much lower pitch than those of the preceding styles. The external roofs of Henry the VII.'s and King's College chapels, for example, are so low in pitch as not to be visible from the ground, being concealed by the elaborate pierced parapets which crown the walls. These pierced parapets form a noticeable feature of the buildings of this period, and often afford very graceful terminations to the structure; but embattled parapets are also common.


Henry VII.'s Chapel, Westminster.

A characteristic feature of this style is the panelling, or panel-work tracery, formed like that of the windows by mullions and transoms, with which both the internal and external walls are sometimes almost entirely covered. Henry VII.'s chapel, Westminster, affords a good example of perpendicular panelling. Stone porches are now numerous; they are often of large size, much enriched with panelling, and canopied niches for statuary, and have handsome groined roofs; the south-west porch of Canterbury cathedral. The south porches of Gloucester cathedral; St. Nicholas chapel, Lynn; Northleach church, Gloucestershire; Addlethorpe church, Lincolnshire; Burford church, Oxfordshire; and Oundle, Northamptonshire, are rich and elegant examples. The church towers during this period are important and characteristic. They are frequently very lofty and much enriched with panelling. Perhaps the finest is that of Gloucester cathedral, erected about 1445; it rises to a height of upwards of 200 feet in two stories, has its surface covered with panelling, and is crowned with four pinnacles at the angles, of extremely light and elegant design. Two celebrated towers of this date were those of Doncaster church, now replaced by a recently erected one of a different character, and of St. Mary's, Taunton, now in course of restoration. Several other west country towers, as St. Stephen's, Bristol; Cirencester, Glastonbury, &c. are fine examples of the style. One of the best towers of late date is that of Magdalen College, Oxford. The towers are not usually surmounted with spires, but there are many spires of this date, and some are of a very elaborate and ornamental character; that of St. Nicholas, Newcastle, is a well-known instance. The buttresses, both of the ordinary kind and flying buttresses, are often of remarkable projection and highly enriched: some illustrations of them are given under BUTTRESS.

In the later examples of the Third Pointed, there is a great excess of ornament, and a constantly increasing deterioration of taste. But so long as the Gothic spirit was retained, in fact till that debased style commonly known as the Tudor was thoroughly established, the English Third Pointed buildings were vastly superior to the contemporaneous Gothic edifices of the continent. As Mr. Willis observes in his admirable 'Remarks on the Architecture of the Middle Ages,' "The Perpendicular is our own, and heartily may we congratulate ourselves upon it, when we compare it with its sister styles of France and Germany."

During its later stages the Third Pointed architecture was greatly more extended, both in its uses and modifications, than the two previous styles, having been applied to domestic as well as ecclesiastical architecture; whereas we are acquainted with the preceding styles only as it was employed in religious buildings; for castellated ones of the same periods have so little in common with the former, and so very few features wherein the general style at all exhibits itself, that they must be considered as forming a distinct class by themselves. In the ornamented domestic architecture of the 15th and early part of the 16th centuries, we plainly perceive the same style as that of ecclesiastical buildings applied to another class, where, although the parts are on a smaller scale and somewhat differently composed, the style of detail and ornament is essentially the same. While some features, such as doors and porches, are very little altered from those of churches, others unknown to the latter class of buildings, such as bay-windows and oriels, chimneys, &c., become highly characteristic and decorative in this. But this domestic architecture only became fully developed as the ecclesiastical was decaying, and hence it is generally spoken of as *Tudor Architecture*. In the reign of Henry VIII. a classic bias began to gain ground in England, as it had some time before spread through the continent; and before it the Gothic spirit paled, and eventually disappeared. At first a few, then gradually more and more, of imitative classic details were mingled with the native forms, until at last resulted that style which in its essence corresponded to what on the continent was known as the RENAISSANCE. Some few and feeble attempts were made to build in the Pointed style as late as the 17th century, but they only served to show how entirely the feeling for what was characteristic of it had departed.

Besides the buildings already referred to, the following may be named as illustrative of the art of this period:—Winchester cathedral, and New College, Oxford, the work of William of Wykeham; the nave of Ripon cathedral; Chester cathedral, and parts of Canterbury, Bristol, Worcester, Wells, and Oxford cathedrals; the Divinity Schools, and several of the colleges, of Oxford and Cambridge; St. George's chapel, Windsor; Eton College chapel; and Redcliffe (Bristol), Beverley, Rotherham, Taunton, Cirencester, Stratford-upon-Avon, and a vast number of other parish churches.

The style Ogival Tertiaire of France is characterised even more than the English Third Pointed by excess of florid ornamentation, which went on increasing till the abandonment of the style for the Renaissance, in the 16th century. It differs in not being characterised by the same tendency to rectilineal lines; though towards the close of the 15th century, panelling, similar in character to the English, was often, though less profusely, employed. The characteristic window tracery is of the lambent flame-like kind from which the style has received its popular title—the *Flamboyant*. The roof vaulting is ramified; in later examples the depressed arch is frequent in doorways. Towers with open spires, often of a degree of lightness quite astonishing in stonework, are seen in churches of a superior class, as at Amiens. The outline and surface are cut up by a crowd of carved foliage, and all kinds of petty ornamentation; but the carving, looked at alone, is often admirably executed. Altogether the buildings show a marked loss of grandeur and purity; but many of them are triumphs of constructive ingenuity. Their builders sought to excite the astonishment of the spectators, and they succeeded. Very fine examples of this style are the churches of St Nisier at Lyon, Pont l'Evêque, Caudebec, Louvois, the cathedral of St. Brieux, &c.

The German architects of the 15th century ran into still greater extravagances than the French; but for notices of the later developments of German Gothic, as well as for that of the Netherlands and Italy (a subject that has lately excited a good deal of attention), we must refer to the works cited below. Here we shall merely add, by way of conclusion, a brief summary of a few of the more prominent distinctions between Grecian and Gothic architecture, as regards the application of their respective elements. *Grecian*: Columns and their entablature are the chief sources of decoration, and limit the height of the building, as a second order cannot with propriety be placed above another. *Gothic:* Columns subordinate members; never used except to support arches, and in the latter styles are mere ornamental shafts attached to piers. *Grecian:* Colonnades seldom employed except externally. *Gothic:* Ranges of open arches applied only internally; there being nothing analogous to a Grecian portico, since porches have merely an open arch in front, and when projecting from the building are closed at the sides. Externally, open arcades are introduced only as upper galleries, and those are of very rare occurrence; or, as a cloister, not projecting from but within the lower part of the building. *Grecian:* Lofty proportions unattainable even in the largest edifices, because the greater the number of columns the lower will the building appear in comparison with its length or breadth. *Gothic:* No restraint as to loftiness, that not being regulated by width even of the whole front or any of its parts. *Grecian:* The pitch of a pediment must be governed by its span, since its height must in no case greatly exceed the depth of the entablature; consequently, the greater the number of columns placed beneath it, the lower it must be, and the lower the proportions of the whole front. *Gothic:* Gables may be of any pitch, just as best accords with construction or the composition of the design. *Grecian:* Little variety of form and proportions in doors or windows, or in regard to their external mouldings; the window itself a mere aperture, without any architectural filling up. *Gothic:* Both doorways and windows very conspicuous features, admitting the utmost diversity, as well in their forms and proportions as in the modes of decorating them.

Windows especially admit of innumerable combinations in regard to their divisions and the ornamental tracery within their arched heads. The same remark applies to the panelling of doors. *Grecian:* All mouldings and other decorative members project from the face of the wall. *Gothic:* All but what are termed weather-mouldings retire within the face of the wall. *Grecian:* No splayed surfaces. *Gothic:* Sloping or splayed surfaces, both horizontal and vertical, very prevalent; in fact, windows and doors are universally placed within splays, more or less deep, and enriched with various mouldings. *Grecian:* No concave mouldings or deep hollows. *Gothic:* Deep hollows of this kind enter into almost every combination of mouldings, whether horizontal or perpendicular.

The most useful general view of English Gothic for the ordinary reader is Mr. Bloxam's excellent little volume, 'The Principles of Gothic Ecclesiastical Architecture,' 10th ed., 1859. For French and German Gothic, a similar survey will be afforded by De Caumont's 'Architecture Réligieuse,' 3rd ed., 1854; and H. Otto's 'Handbuch der Kirchlichen Kunst-Archæologie des Deutschen Mittelalters,' 3rd ed. 1854. Mr. Fergusson's valuable 'Illustrated Handbook of Architecture' affords a broad summary of the characteristics of all the schools of Gothic architecture. Those who wish to carry their investigations deeper will find great assistance in the following works, which, however, are but a very few of the many elaborate works on mediæval architecture published within the last few years:—Gailhabaud, 'Monuments Anciens et Moderns,' and 'L'Architecture du Ve au XVI^e^ Siècle,' 4to, 1851; Chapuy, 'Moyen Age Monumental;' L. Drouyn, 'Architecture au Moyen Age;' Viollet le Duc, 'Dictionnaire raisonné de l'Architecture Française du XI^e^ au XVI^e^ Siècle;' Bourassé, 'Les Cathedrals de France;' A. Lenoir, 'Architecture Monastique;' F. Stroobant, 'Monuments d'Architecture, &c., en Belgique,' 4to, 1852; J. L. Petit, 'Architectural Studies in France,' 1854; Whewell, 'Architectural Notes on German Churches,' 3rd ed.; G. Moller, 'Denkmäler der Deutschen Baukunst' (fol.), the text published in England under the title of 'Memorials of German Gothic Architecture, translated by W. H. Leeds;' G. G. Von Kallenbach, 'Atlas zur Geschichte der Deutsch-Mittelalterlichen Baukunst,' fol., 1847; Boisserée, 'Denkmale der Baukunst vom 7ten bis zum 13ten Jahrhundert am Nieder Rhin,' fol., 1833; Springer, 'Die Baukunst des Christlichen Mittelalters,' 8vo, 1854; Gally Knight, 'The Ecclesiastical Architecture of Italy;' Cresy and Taylor, 'Architecture of the Middle Ages in Italy;' Street, 'Brick and Marble Architecture of Italy in the Middle Ages;' Ruskin, 'Seven Lamps of Architecture,' and 'Stones of Venice;' Willis, 'Remarks on the Architecture of the Middle Ages;' A. F. Von Minutoli, 'Der Dom zu Drontheim, und die Mittelalterliche Christliche Baukunst der Scandinavischen Normannen,' fol., 1853; Brandon's 'Analysis of Gothic Architecture;' Garbett's 'Rudimentary Treatise on Design;' and the works of Rickman, Britton, Pugin, Paley, Sharpe, Freeman, &c., with the illustrations of the cathedrals, &c., by Carter, Winkles, Le Keux, &c.

GOTHIC LANGUAGE. It is now generally admitted that the Gothic language or languages is or are a branch of the Teutonic family. (J. Grimm, 'Deutsche Grammatik,' and H. Meidinger, 'Vergleichendes Etymologisches Wörterbuch der Gothisch-Teutonisch Mundarten,' 8vo., Frankfort on-the-Main, 1833.) The Altgotisch, or old Gothic, was the language of the Goths who lived near the banks of the Lower Danube in the 4th century, and for whom Ulfilas made a translation of the Gospels, of which the greater part exists in the silver book preserved in the library of Upsala. [ARGENTEUS CODEX.] Ulfilas was bishop of those Goths who lived in Mœsia in the time of the Emperor Valens, and the language of his version has been styled Mœso-Gothic. He is believed to have invented the characters employed in the version, and which are formed, with slight variations, from the Greek and Latin capitals. [ALPHABET.] This and a few other fragments, chiefly scriptural, of about the same age, are all the remains of a language once spoken by the West-Goths, or Visigoths of Spain, and the Eastern Goths of Hungary and Italy. It had five vowels, and four dipthongs, ai, au, ei, and iu; and the conjugations were even more complete than the present Swedish. Another branch of the Gothic or Gotho-Teutonic language existed in Scandinavia, which German philologists have called Altnordisch, or old Norse, and in which the 'Edda' is written, and which is still spoken with some variations in Iceland, the Faroe Islands and parts of Norway. (Meidinger). Out of this language the modern Swedish, Danish, and Norwegian sprung. Inscriptions in the old Norse, or Scandinavian Gothic, have been found in several parts of Sweden, Denmark, and in the island of Gothland, in various characters different from those of Ulfilas's Mœso-Gothic versions. Bonaventura Vulcanius, the editor of Jornandes' 'De rebus Geticis,' published also an anonymous treatise on the Gothic language; 'Commentariolum Viri cujusdam docti anonymi in Literas Gothicas,' with specimens of the Mœso-Gothic, old high German, Anglo-Saxon, and other old Teutonic dialects, followed by four different Scandinavian Gothic alphabets collected from various inscriptions, and one of which is similar to the one given by Magnus in his 'Historia Gothorum Sueonumque,' b. i. ch. 7. The old Scandinavian, or Norse, or Suio-Gôthic, is considered by Adelung as being a mixture of Gothic with the language of the Sveones, the original inhabitants of the Scandinavian peninsula, previous to the Gothic immigration, and the modern Swedish, which is derived from the old Scandinavian, appears to have elements in it foreign to the Teutonic, though the Teutonic, or Gothic, greatly prevails in both.

(Petersen, *Det Danske, Norske, og Svenske Sprogs Historie*, Copenhagen, 2 vols. 8vo., 1830.)

GOTHS, GOTHI, GOTHONES, a powerful northern nation who acted an important part in the overthrow of the Roman empire. Tacitus ('German.') mentions the Gothones as a German tribe, dwelling between the Lygians and the Rugians and Lemovians, the last two possessing the shores of the Baltic, while he considers the Gothini, who lived in Southern Germany, as a tribe of Celts, or Gauls. Ptolemy calls them Gothunes, considers them to be a Sarmatian tribe, and places them south of the Wends, and eastward of the Vistula.

About the middle of the 3rd century the Goths are recorded to have crossed the Dniester and to have devastated Dacia and Thrace. The emperor Decius lost his life in opposing them in Mœsia, A.D. 251, after which his successor, Gallus, induced them by money to withdraw again to their old dwellings on the Dniester. They then seem to have spread eastwards, and to have occupied the country about the Cimmerian Bosphorus, from whence they sailed across the Euxine, occupied Trebisond, and ravaged Bithynia. In the year 269 they landed in Macedonia, but were defeated by the emperor Claudius II. Three years after, Aurelian gave up Dacia to a tribe of Goths, who are believed to be the Visigoths, or Western Goths, while those who ravaged Asia Minor were the Eastern Goths, or Ostrogoths. This distinction of the race into two grand divisions appears about this time. Under Constantine I. the Goths from Dacia invaded Illyricum, but were repelled; afterwards Constantine II. allowed a part of them to settle in Mœsia, who seem to have soon after embraced Christianity, as it was for them that Ulfilas translated the Scriptures, about the middle of the 4th century, into the dialect called Mœso-Gothic. [GOTHIC LANGUAGE.] About the year 375, the Huns, coming from the east, fell upon the Ostrogoths, and drove them upon the Visigoths, who were living north of the Danube. The latter, being hard pressed, implored permission of the Roman commander to be allowed to cross that river, and take shelter on the territory of the empire. The Emperor Valens consented, and a vast multitude of them were allowed to settle in Mœsia; but soon afterwards they quarrelled with the Roman authorities, invaded Thrace, and defeated and killed Valens, who came to oppose them. From that time they exercised great influence over the Byzantine court, either as allies and mercenaries, or as formidable enemies. Towards the end of the 4th century, Alaric, being chosen king of the Visigoths, invaded North Italy, but was defeated by Stilicho near Verona. He came again, however, a few years after, and took and plundered Rome. His successor, Ataulphus, made peace with the Empire, and repaired to the south of Gaul, where the Visigoths founded a kingdom, from which they afterwards passed into Spain, where a Visigothic dynasty reigned for more than two centuries, till it was conquered by the Moors. Meantime the Ostrogoths, or Eastern Goths, who had settled in Pannonia after the destruction of the kingdom of the Huns, extended their dominion over Noricum, Rhætia, and the Illyricum; about the year 489, they invaded Italy under their king Theodoric, and defeated Odoacer, chief of the Heruli, who had assumed the title of king of Italy, a title which Theodoric then took for himself with the consent of the Eastern emperor. Theodoric was a great prince: his reign was a period of rest for Italy, and his wise administration did much towards healing the wounds of that country. But his successors degenerated, and the Gothic dominion over Italy lasted only till 554, when it was overthrown by Narses, the general of Justinian. From that time the Goths figure no longer as a power in the history of Western Europe, except in Spain. We find however their name perpetuated long after in Scandinavia, where they probably arrived from some country east of the Vistula, or even as the Icelandic traditions assert, from the neighbourhood of the Caspian sea, at some time preceding that of their moving southward. A kingdom of Gothia existed till the 12th century distinct from Sweden Proper, until both crowns were united on the head of Charles Swerkerson, in the year 1161, who assumed the title of king of the Swedes and the Goths, which his successors bear to this day.

GOUT (*gutta*, a drop). This name was given to the disease which we are about to describe, from a fanciful notion that it arose from some morbid matter, deposited by drops in the joints. In technical language gout is called *Arthritis* or *Podagra*. It may be defined to be an inflammatory affection of the joints, arising from a morbid action in the system. It is mostly an hereditary disease, coming on without any evident external cause, generally preceded by disorder of the digestive organs, and accompanied by a plethoric state of the system. The inflammation attacks the smaller joints, particularly the first joint of the great toe, and returns at intervals, various joints or parts becoming affected after repeated attacks.

A paroxysm of gout is generally preceded by some constitutional disturbance, though it may attack a person suddenly who is apparently in good health. It is commonly ushered in by a disordered state of the whole system; both the circulating, nervous, digestive, and secreting organs are out of order. The pulse is frequent and full; there is a feeling of repletion and oppression; drowsiness or restlessness; general lassitude and depression of spirits; flatulence; irregular appetite; costiveness; and high coloured urine, which deposits a pink sediment on cooling. The local affection generally commences suddenly in the middle of the night. The patient is awakened at two or three o'clock in the morning with acute pain in the ball of the great toe, accompanied with a feeling of heat and stiffness of the part: chilliness and fever come on, which gradually abate as the pain increases, which becomes more violent every hour, having a burning or gnawing character. This generally continues till the middle of the following night, though in slight cases it may remit after a few hours' duration. A gentle perspiration then breaks out, and the patient falls asleep. The next morning the toe is shining, red, and swelled; the veins of the foot are very much distended, and the joint is excessively tender. Exacerbations, becoming less violent each time, recur for several nights, and then the attack declines. The joint remains swelled and weak for some days, and there is violent itching, followed by desquamation of the cuticle; after which all disease ceases, and the patient feels better, both in body and mind, than before the attack.

Such are the history and course of a simple fit of gout, as it generally occurs on its first attack. In subsequent seizures, the inflammation, on subsiding in one joint, frequently attacks another, and eventually several joints may be attacked in succession, or two or more at the same time, as the fingers, wrists, and knees. Generally the intervals between the attacks grow shorter, the patient has more and more frequent fits, and they last longer; but this will depend in a great measure on the treatment pursued, and the mode of life of the patient. The fits are more liable to occur in the spring and autumn than at other seasons, owing perhaps to the greater variableness of the weather at those times of the year. After repeated attacks the joints may become stiff and rigid: deposits of whitish matter, called chalk-stones [Calculi] (which principally consist of urate of soda), will take place beneath the skin, so that the joints of the fingers and toes become enlarged and swollen.

It is very common, when persons have had gout for a length of time, for various internal organs to become diseased. The inflammation may suddenly disappear from a joint, and some serious internal affection, as apoplexy or gastritis, unexpectedly make its appearance. This is called retrocedent or displaced gout. The internal affections which thus arise are often caused by the patient's imprudence, and sometimes by injudicious treatment, as the application of cold to the inflamed joint.

We have mentioned among the precursory symptoms of an attack of gout, that the urine is frequently turbid, and deposits a lateritious sediment. There seems to be a tendency to throw off morbid matter from the overloaded system by this outlet. It has been said that gout favours the formation of urinary calculi, and numerous cases are related where stone in the bladder, or gravel, has occurred in connection with this disease. Irritation of the urinary organs is certainly very common in gouty persons.

Gout is more frequently met with in persons of vigorous and robust constitutions, than in those of spare habit; and is more common in men than in women: this comparative immunity of the female sex seems to be owing in a great measure to their more temperate habits of life. Persons of advanced and middle age are more liable to gout than those of early life. It does not commonly appear till after the age of thirty-five, though where the predisposition is strong it may occur even before puberty. Hereditary predisposition is doubtless a cause of gout, and where this tendency exists the disease may take place under circumstances which would not otherwise have power to produce it. Hence persons who are conscious of an hereditary taint should guard with particular care against the causes which excite gouty action. The most active of these is a plethoric or inflammatory state of constitution, arising from luxurious living, indolence, and sedentary habits; which also give rise to that disordered state of the digestive organs which constantly precedes an attack of gout.

Where the predisposition, both hereditary and acquired, strongly exists, a very slight cause may excite the paroxysm. A fit of intemperance, or excessive indulgence in eating, may bring it on. Excitement of mind from anxiety or intense study will sometimes cause a fit of gout; and it has been known to follow violent exercise, particularly walking. An accident or injury of a joint, occurring in a gouty subject, instead of causing simple inflammation, may give rise to an attack of gout. Gout possesses a considerable resemblance in many of its characters to rheumatism, and these affections are in some instances confounded together. There are even modifications which partake so much of the characters of both, that they go by the name of rheumatic gout. Gout however may generally be known from rheumatism, by its attacking persons later advanced in life and of a full habit; by its affecting principally the smaller joints, and being commonly confined to one, at least in its earlier seizures; the attack of gout also declines more quickly, is preceded in most cases by disorder of the digestive organs, and is not brought on by any external exciting cause, as cold and damp, which is mostly the case in rheumatism.

With regard to the cause of gout, and the state of the system in which it comes on, considerable light has been thrown upon them by the researches of Dr. Garrod. He has shown that the retention of uric acid in the blood is the first of a series of changes, which results in the deposition of urate of soda in the joints or other parts affected with the gouty inflammation. The following are the conclusions at which Dr. Garrod has arrived and which he has published in his work 'On the Nature and Treatment of Gout.'

First. In true gout, uric acid is invariably present in the blood in abnormal quantities in the form of urate of soda.

Secondly. True gouty inflammation is always accompanied with a deposition of urate of soda in the inflamed part.

Thirdly. The deposit of urate of soda is crystalline and interstitial, and when once the cartilages and ligamentary structures become infiltrated, such deposition remains for a lengthened time, perhaps during life.

Fourthly. These deposits are the cause and not the effect of gouty inflammation.

Fifthly. The attack of gouty inflammation tends to destroy the urate of soda in the blood of the part, and in the system generally.

Sixthly. The kidneys are early implicated in gout, and this affection is not only functional, but eventually becomes structural. The urine in gout is always altered in composition.

Seventhly. The presence of urate of soda in the blood, is probably the cause of the premonitory symptoms of an attack of the gout, and of the anomalous symptoms which are known to present themselves in gouty subjects.

Eighthly. The causes known to predispose to the gouty attack are such as produce an increased formation of uric acid in the system, or which leads to its retention in the blood.

Ninthly. The causes exciting a fit of the gout are those which reduce the alkalinity of the blood, or augment the formation of uric acid, or temporarily check the power of the kidneys in eliminating this principle.

Dr. Garrod's theory has certainly the merit of explaining the anomalies presented in the history of gout. It shows that the tendency of the kidneys to refuse the elimination of uric acid may be hereditary, and it also explains that in poor systems, as well as plethoric ones, this tendency of the kidneys may serve to bring on an attack of gout.

The occurrence of a paroxysm of gout often seems to relieve the general health for a time; and it is a common idea that an attack expels the morbid matter from the system. Although this is true to a certain extent, it is a dangerous doctrine to put in practice. It has often led to very improper and even dangerous proceedings. On the contrary, the judicious plan of treatment in gout is to moderate the paroxysm and prevent its recurrence. It would be out of place here to enter into any detail of the numerous plans of treatment and the remedies which have been adopted in gout. With regard to the preventive treatment, we need only recommend temperance and exercise, which will generally succeed in keeping off a recurrence of the disease, and if strictly adopted will be a sufficient guidance to the gouty patient. There is an old Scotch proverb, and a very true one, "that a man might cure himself of gout by living on sixpence a day, and working for it." The treatment of the paroxysm is very simple. The inflammation should be subdued in this case by the same means as would be requisite in inflammation from any other cause. If the patient be plethoric, and there is active fever, we must bleed, purge, and starve him. Should there be less constitutional disturbance, we may safely leave the fit to run its course; for gouty inflammation has a natural tendency to subside spontaneously, without terminating in suppuration. Alkalies and saline medicines which act as purgatives and diuretics are also to be recommended. Dr. Garrod also recommends the salts of lithia.

Topical remedies are of little use in gout. Warm applications do no good, and cold ones may do serious harm by suddenly checking the inflammation, and bringing on dangerous affections of internal organs. If anything be applied to the part, a warm evaporating lotion is perhaps the best thing.

In addition to the general antiphlogistic treatment which we have mentioned, we possess a remedy which certainly is highly valuable in gout, namely, colchicum. This medicine, when given in a sufficient quantity, generally purges the bowels, and lowers the pulse. A large dose of this drug, given when the occurrence of a paroxysm is threatened, will often avert it altogether, but the prudence of this mode of proceeding is very questionable; it only suppresses the paroxysm, without removing the constitutional disorders on which the disease depends. Colchicum may be given with safety during a fit of gout, and it certainly seems to shorten its duration. The colchicum (of which the wine of the seeds is one of the best preparations) may be given, and repeated in moderate doses three or four times a day, either alone, or combined with purgatives. As soon as free purging is produced, the symptoms are generally relieved. Some authors are of opinion that the colchicum does no good without it acts upon the bowels; but in many instances, before this effect is produced, it will allay the pain, bring down the pulse, and stop the progress of the paroxysm. Colchicum is said to increase the secretion of uric acid by the kidneys, but this is denied by Dr. Garrod, who has carefully investigated the subject. This drug is the active ingredient in the *eau médicinale* and other quack medicines which are in general use as specifics for the cure of gout.

With respect to the treatment of the complex conditions and different varieties of gout, it must be directed to the improvement of that disordered state of constitution upon which they depend.

Persons of a gouty habit are liable to certain inflammatory affections of the eye (dependent on the state of the constitution), which differ in some respects from inflammation of the same parts arising from other causes. The external proper tunics, particularly the sclerotica, may be affected in the gouty; though in this case the iris generally participates in the inflammation. The sclerotica and conjunctiva may however be attacked without the iris in gouty persons; this affection is then similar to that modification of external ophthalmia which occurs more frequently from exposure to cold in persons who suffer from rheumatism, and is denominated rheumatic ophthalmia. [RHEUMATISM.]

Sometimes gouty inflammation of the sclerotica is accompanied with an erysipelatous form of inflammation of the conjunctiva. Beer has seen this follow the suppression of gout in the feet by cold.

Inflammation of the iris (arthritic iritis) is a much more common affection than the last in gouty persons, and is usually of an acute character. It commences with uneasy sensations in the eye, which are followed by pain about the orbit, forehead, and side of the head, and lastly in the eye itself. Redness of the sclerotica comes on, which is particularly seen round the cornea; attended with watering of the eye, and intolerance of light. The iris soon becomes dull and discoloured, the pupil is contracted, and fixed at one or more points to the capsule of the lens. It has been observed that the red zone round the cornea is less bright in this than in other forms of iritis [IRITIS]; and, as in rheumatic ophthalmia, does not quite extend to the cornea, but leaves a narrow white ring between them. This form of iritis often returns again and again, the eye recovering almost completely after repeated attacks. The iris however often becomes attached to the capsule of the lens by whitish adhesions, though without causing much injury to vision. Mr. Lawrence says that gouty inflammation, when severe and long-continued, sometimes causes complete disorganisation, with puckering, and tubercular projection of the iris, and extinction of sight. When arthritic iritis occurs in a person of plethoric habit, we must bleed and adopt general antiphlogistic treatment. Colchicum may also be given with advantage. Mercury seems to do more harm than good in this affection. The recurrence of the disease must be prevented by such means as remove the gouty disposition.

Besides the affections which we have described, persons of a gouty constitution are sometimes attacked with more extensive inflammation of the eye, affecting the internal parts of the globe generally; that is, the choroid membrane, iris, retina, vitreous humour, lens and its capsules, and secondarily involving the sclerotica and cornea. It generally ends in loss of sight, with a dilated pupil and opaque lens; but in some cases the latter change does not take place, and a green discoloration of the pupil remains: in this case, Mr. Lawrence calls the affection *acute glaucoma*. Arthritic inflammation of the internal tunics is a much more serious disease than gouty iritis, and almost invariably destroys sight. It is attended with great suffering; there is severe burning pain, which extends to the face and side of the head; and the eye itself feels distended, or swelled. There is redness of the sclerotica and conjunctiva; dulness of the cornea and iris; the pupillary margin of the latter is turned backwards, and the opening itself dilated and fixed. The lens becomes opaque, and often of a greenish colour, and is pushed forward into the dilated pupil; the eye loses its brilliancy and looks dead. The sight is lost at an early period of the disease. This disorder generally affects both the eyes in succession, and the most energetic treatment has hardly any effect upon it. Loss of blood, and other active measures, must be resorted to in the first stage of the affection. This disease is generally seen in elderly persons of full habit, with bloated red faces which are owing to indulgence in the pleasures of the table. These affections of the eye are sometimes due to rheumatic states of the system, which differ essentially from those of gout. [RHEUMATISM.]

GOVERNMENT is a word used in common speech in more than one sense. 1. It denotes the *act of governing*, as when we speak of "the business of government." 2. The *persons who govern* are, as often as not, called "the government;" and we thus speak of "the French government," "the Russian government," &c. 3. The word "government" is used elliptically for the phrase *form of government*, as when we speak of "a monarchical, aristocratical, or republican government;" or, again, of "the English or French government," meaning thereby the English or French form of government, or (changing the phrase) the English or French constitution.

The science of government, or the science which relates to the business of government, is more commonly called the science of legislation. So the art which flows from this science, or the art of governing, is called the art of legislation. In accordance, then, with the common phraseology, we shall now dismiss this first of the two sciences, and together with it that sense of the word "government" in which it signifies the act of governing; reserving them for treatment under the head LEGISLATION. In the present article we shall concern ourselves exclusively with that sense of the word "government" in which it stands for the phrase "form of government," confining ourselves to an enumeration of the various forms of government.

1. A government consists either of one person or of more than one.

When it consists of one person only, the appropriate name for the form of government would be *monarchy*. But we shall see hereafter that this name is generally, in common speech, fantastically bestowed on a particular class of governments of more than one; while a government of one only is called by the names of *absolute monarchy*, *despotism*, and *tyranny*. Of these three names, the last two may be objected to as names, because they always imply disapprobation, or because they are not only names, but also (to employ Mr. Bentham's phraseology) words dyslogistic. But the essence of this form of government is the complete dependence of the governed on the will of one person, which is well expressed by the terms despotism and tyranny; and the sense of disapprobation which hangs about these terms, or their dyslogistic character, is to be traced to the accidental circumstance of the conjugate terms *despotic and tyrannical* being commonly used to describe other forms of government, in which the arbitrary conduct of the governors resembles that of the generality of despots or tyrants.

2. A government of more than one may either consist of one homogeneous body, or (changing the phrase) of one body all whose members are appointed in the same way, or it may be mixed, compound, or consist of heterogeneous parts.

When the members of the one governing body, if hereditary, are a decided minority of the state, or, if deriving their powers from without their own body, they so derive them from a portion of the state which is yet a decided minority, the government is called by the names *aristocracy* and *oligarchy*. There is a difference in the use of these two terms which it is impossible to mark exactly. But it may be said roughly that the term oligarchy is used where the minority is very small, and the term aristocracy where it is not. The latter term also would be always employed where the members of the governing body derive their powers from without, or where the body is elective.

When, again, the members of the one governing body either themselves constitute, or derive their powers from, a portion of the state which is a decided majority, the government is called a *democracy*.

3. Before proceeding any further with that series of divisions, in which we have now taken two steps, we may remark that the three forms of government of which we have now spoken—namely, absolute monarchy or despotism, aristocracy or oligarchy, and democracy—are commonly called (as being governments of one person, or of one homogeneous body) pure forms of government, in contradistinction to the mixed forms which yet remain to be considered. The division of forms of government into pure and mixed is a complete division, which the common division into monarchy, aristocracy, and democracy, is not.

4. A mixed form of government is one compounded of the whole or of any two of the three elements which exist separately in the three pure forms of government, and also of individuals or bodies deriving their powers from different portions of the state, even though each of these different portions is a decided majority of the state. It is not necessary to enumerate all the mixed forms of government which arise from all the possible combinations. Besides that all the possible combinations may be easily seen, some of them produce forms of government which have never existed, and which consequently are no objects of interest. It will be sufficient, then, to speak of those combinations, or rather of those classes of combinations, with which men are familiar, and for which common speech supplies names.

The mixed forms of government which occur may be divided into two classes, according as an hereditary chief does or does not enter into their composition.

Governments which contain an hereditary chief united either with an aristocratic and a democratic body, or with an aristocratic body by itself, or with a democratic body by itself, are generally called *monarchies*. They are also called *limited monarchies*, as if to distinguish them from the governments of one only, to which, as we have said, the name monarchy more appropriately belongs, but to which, without the epithet *absolute* being prefixed, it is seldom or never applied.

As regards the governments of which an hereditary chief forms no part, it will be convenient to observe at the beginning, that the combinations of an elective chief with one or more democratic bodies are the only combinations which possess any interest for men; if, indeed, judging from the past, we may not also say that they are the only ones which are practicable. And having premised this, we may say that the governments into the composition of which an hereditary chief does not enter are generally called *republics*, or *representative governments* (the relation of the democratic body or bodies in the government to the portion or portions of the state that appoint them being known by the name representation), or, again, *pure representative governments*, as if to distinguish these from the forms of government in which a democratic body is united either with an hereditary chief and aristocratic body together, or with either of these by itself.

It is scarcely necessary for the objects of a Cyclopædia, which seeks to collect facts rather than to advance opinions, to enter upon the question of which is the best form of government.

GRACE, DAYS OF. [BILL OF EXCHANGE.]

GRACE. This word is frequently used in the Scriptures to denote in general the favour and love of God towards mankind, and also more particularly as manifested in the gift of his son Jesus Christ. (2 Cor. viii. 9.) It is also employed to designate that degree of divine influence upon the mind which enables an individual to believe in the Gospel. Grace is sometimes used in opposition to the law, and to express the happy condition of those who experience its benefits (Gal. v. 4, 5). Also the benefits themselves, or the gifts of the Holy Spirit (John i. 14, 16). Some theologians maintain that there are two kinds of grace, which they designate as *common* and *special;* the former consisting in such divine influences as operate beneficially upon the moral character, but leave the mind without real faith; the latter, which is necessary for salvation, being granted only to such individuals as have been elected to everlasting life. [ELECTION.] There is also difference of opinion among theologians on what is called *irresistible grace*, many considering "that grace may be resisted and rendered ineffectual by the perverse will of obstinate sinners;" while others believe "that it is never on the whole finally rejected, so as to fail working faith in those who are the happy subjects of it."

GRACES, GRA'TIÆ, or CHARITES, in ancient mythology, are represented as three young and handsome sisters, the attendants of Venus. Their names were Aglaia, Euphrosyne, and Thalia. Homer mentions but one Charis. The Lacedæmonians had only two, whom they called Kleta or Klyta, and Phaënne, and a temple in honour of them existed in the time of Pausanias between Sparta and Amyclæ (iii. 18; ix. 35). Hesiod, however, speaks of three. Some poets name Pasithea as one of the Graces. The idea of the Graces was, according to some, originally a symbolic personification: Aglaia represented the harmony and splendour of the creation, Euphrosyne represented cheerfulness and mirth, and Thalia feasts and dances. In short, they were an æsthetic conception of all that is beautiful and attractive in the physical as well as in the social world. Some called them the daughters of Zeus by Hera, Eurynome, Harmonia, or Lethe; others of Dionysus and Aphrodite; others, again, of Apollo and Enanthe. Their worship is said to have originated in Bœotia. They were originally represented as lightly clothed, but in latter times the sculptors made them entirely naked: they are usually figured holding each others hands or embracing, and bearing ears of corn or flowers. They were invoked to preside at the festive board, at nuptials, at births, &c. Their images were multiplied on an infinite number of sculptures, paintings, gems, and votive inscriptions were affixed to them. Groups of the three Graces have been found, forming one of the most pleasing representations of ancient art; and modern sculptors, Canova among the rest, have sought to rival the ancients in reproducing the same subject. (Millin; Hirt; Müller.)

GRADIENTS. [RAILWAY.]

GRADUATE. [ARTS, DEGREES IN.]

GRADUATION is the name commonly applied to the art of dividing mathematical and astronomical instruments. The nature of this work will not admit of a detailed account of the various methods and machines used in different branches of the art; we shall only give an outline of the different processes, with reference to the standard authorities, and add a few suggestions for the consideration of the astronomer and artist.

Graduation, or, as the workmen more generally style it, *dividing*, is performed in two ways, by making a *copy* of a system of divisions already existing, or by *original* dividing. The straight scales and rules which are in common use are divided thus:—The original pattern, and the scale on which the copy is to be laid, are placed side by side; a straight edge, with a shoulder at right angles, like a carpenter's square, is made to slide along the original, stopping at each division, when a corresponding stroke is cut by the dividing knife on the copy. With care and practice, this method admits of considerable accuracy. By making the straight edge turn on the centre of a divided circle, the divisions of that circle may be copied upon any concentric circle. Common protractors are thus divided, and scales upon circular limbs. The original circle, which may have several orders of divisions for different purposes, is called a *dividing plate*.

The above method requires a *standard*, which must be divided *originally*. This will be noticed hereafter.

Small theodolites and ordinary circular instruments must have been thus divided, previous to the invention by Ramsden of his *dividing engine*. The errors were of course large, and Mayer proposed to get rid of them by his principle of *repetition* [REPEATING CIRCLE]; but Ramsden's discovery of a machine for rapid and accurate dividing was better adapted to ordinary purposes. The general principle of Ramsden's dividing machine may perhaps be understood by the following description:—A horizontal circle of four feet diameter turns upon a vertical axis; the outer edge is ratched, or notched, by an endless screw, one revolution of which carries the circle round 10′; the pressure of the foot upon a treadle turns the screw forward, and there is a series of very ingenious contrivances which enable the divider to turn the screw through any portion of its revolution at each descent of the treadle, and which restore the position of the parts, when the foot is taken off, without allowing any return motion to the screw. The circle to be divided is fixed upon the dividing engine, and made concentric with it, and a division cut after each pressure of the foot. The Board of Longitude gave Ramsden a reward of 300*l.* for the invention of this machine, and 315*l.* for the machine itself, leaving it, during pleasure, in his possession, on condition that he would divide sextants at 6*s.* and octants at 3*s.*, for other mathematical instrument makers. Machines of a similar kind, with some alterations and improvements, have since been constructed by John Troughton, Edward Troughton, and others, and these are still employed in all instruments which are not large enough, or not sufficiently valuable, to require original dividing.

Ramsden invented a machine for dividing straight lines, in which he used a screw as his original. In the form proposed by Ramsden the machine has not been deemed of any value, since a long screw can never be made so accurate as a scale divided by bisections. Mr. Bryan Donkin has contrived a machine where a screw is indeed the scale, but where the errors of the screw are corrected by additional mechanism. We do not think that this machine has ever been figured or described, but scales have been divided, and screws cut by it of extraordinary accuracy.

Dividing engines have been constructed somewhat differently by Reichenbach and others in Germany, and by Gambey in Paris. Much of the German division is excellent, and probably superior to any English engine-dividing. It is understood to be performed by copying. A large circle having been divided originally with great care, the copy is placed upon it, and concentric with it. A microscope is fixed independently over the divided circle, the divisions are brought in succession under the wires of the micrometer, and a line is cut in the copy after each bisection. This process is much more tedious than the English engine-dividing, but it admits of the greatest accuracy when the workman is careful and expert. It is a defect in the English engine that the circle to be divided must be detached from its centre and framing, and that when reframed there is frequently a sensible excentricity, that is, the centre of the divided circle is not in the axis of rotation. This does not, however, cause any error if two or more opposite readings be used. It is a worse fault, that if the instrument be badly framed the circle may become distorted when the instrument is again put together. But when the divided limb is only a part of a circle, as in the sextant, any error of excentricity is of serious importance, and this error may be very sensible after the utmost care of the artist. [SEXTANT.] Gambey has constructed a dividing engine, by which the instrument is divided upon its own centre, but we cannot here describe the contrivance, and are not aware that it has been published.

It has not, we believe, been ascertained what average amount of error is to be feared in an English circle, engine-divided. We have not been able to learn a more important point, whether circles from the same engine are fac-similes. If they are, it would be easy to determine the error of one copy, and to apply correcting pieces to the stop of the dividing screw. This point is worth the attention of the artist, for if the engine does always give the same result, the correction would neither be troublesome nor expensive; and if it does not, nor can be made so to do, the German mode of copying must be followed where great accuracy is necessary.

In what has preceded, the existence of a standard is presumed; we will now give a brief and necessarily imperfect sketch of the art of *original* dividing. Before the invention of the telescope, almost any mode of division must have been sufficiently accurate. In a circle of three feet radius, 1′ is rather more than 0·01 inches, a quantity the half or third of which is readily seen and still more easily felt, so that the observations of Tycho and Hevelius might very well have been exact to 10″ if their greatest errors had arisen from the erroneous division of their instruments. The earliest essays in dividing which we are aware of are those of Hooke and Roemer. Hooke proposed to cut the edge of his quadrant by an endless screw, just as in Ramsden's engine, and to use the revolutions and parts of the screw as a division. This was done in Flamsteed's sector, constructed by Tompion, probably under Hooke's control, and also in his mural arc, but both the limbs were also divided into degrees by diagonal lines, &c.; and in the 'Historia Celestis,' the revolutions and parts of the screw are set down, as well as the divisions. It is found in practice that such a mode of dividing is liable to very considerable errors unless checked and corrected by independent divisions. Roemer, when he had constructed his transit-circle, directed his pupil Horrebow to describe a number of concentric circles on the limb, very near each other, and then to divide them into equal parts by *stepping* along each with a pair of compasses opened to a space of about 10′. All that he required was to have the dots round and the spaces equal; the actual value of each space was to be ascertained by finding how many were contained in the arc of 90°, *between the pole and the equator*. Horrebow informs us that only one of these series of divisions was executed which turned out exact enough to satisfy Roemer. The objection to this division is the same as to Hooke's endless screw, that there is no check upon an accumulation of small errors; still it is probable that Roemer's circle was the best divided instrument then in existence, and the idea of determining the value of the parts by observation is worthy of its author. We have no account of the way in which either Flamsteed's sector or his mural arc was was divided. All we know is that the latter instrument was divided by the "skilful hand of Abraham Sharp," then Flamsteed's assistant.

The art of dividing assumed a new form under the celebrated Graham, the father of all good clock, watch and instrument making in this country, and the worthy associate of Bradley. He pointed out the fundamental principle of original graduation, that you can divide a given line accurately into two parts, but not into three or five equal parts. The dividing tool employed by Graham was the beam-compass, a straight rod of wood or metal, on which perpendicular points of steel are fixed. Now if a line or arc is to be bisected, the points of the beam-compass are placed *nearly* at the distance of half the line, or the chord of half the arc between the dots. One point is placed in one dot, and a faint arc is struck with the other point towards the distant dot, and this operation is repeated with the second dot as a centre. The two faint arcs will either include a small space, or leave a small space between them, which can be most accurately divided with a pointer by the hand, aided by a magnifying lens. In the mural quadrant which Graham erected at Greenwich, he carried this principle into full operation. The beam-compass, which was used for drawing the divisional arc of the quadrant, was used for setting off the chord of 60°; this was bisected, and the radius being again set forward from 30°, he had the quadrant exact. The arc of 60° was divided by continual bisections into 64 (or 2^6) equal parts, and the arc of 30° in like manner into 32 (or 2^5) parts. The subdivisions were, on the same principle, into 16 parts each. This division of the quadrant into 96 parts was continued as long as quadrants remained in use, but the trouble of reducing every observation into ordinary degrees, minutes, and seconds, was a considerable increase of labour to the observer. The quadrants were generally divided to 90 as well as into 96 parts, and in Bradley's and Maskelyne's 'Greenwich Observations,' the zenith distances are recorded in both divisions, with a recommendation to trust to the 96 division in cases of discrepancy. The improvements introduced by Bird chiefly apply to the division into 90°. He made a long scale of equal parts by stepping three times with a beam compass 51·2 inches, and subdivided each of these parts by continual bisections into tenths. For further subdivision, a space of 25,856 inches was taken and divided into 256 parts by perpetual bisection; hence, as each of the new spaces was 0·101 inches, he had, with his vernier, a scale of equal parts to 0·001 of an inch. From such a scale of equal parts as this and the proper tables, all the lines of Gunter's and other scales are laid off upon a standard. In dividing the mural quadrant Bird made great use of his scale, chiefly to obtain the arc of 85° 20′, which admits of perpetual bisection, being 1024 × 5′. The chords of the several arcs were computed and beam-compasses prepared, which were adjusted by the scale to be the chords 30°, of 15°, of 10° 20′, and of 4° 40′, to the proposed radius. The scale, quadrant, and beam-compasses were then left all night to come to the same temperature, and before sunrise were examined, and readjusted if incorrect. The arc being struck, the radius marked off the chord of 60°, which was bisected with the beam-compass containing the chord of 30°, and the radius protracted from 30° gave the quadrantal arc exactly as in Graham's mode of dividing. The arc between 60 and 90 was then bisected in 75° by its proper beam-compass, the chord of 15°, and then the chord of 10° 20′ was carried forward from 75°, and the chord of 4° 40′ was carried backwards from 90°. The exact joining of these two chords in the same point proved the accuracy of the operation. The fifth beam-compass had been set to the chord of 42° 40′ and with this the arc of 85° 20′ was bisected. When this part had been subdivided, the chord of 64 subdivisions, or of 5° 20′, was taken from the divided portion and carried forward from 85° 20′, and then perpetually bisected. Bird remarks "that the points at 30°, 60°, 75°, and 90° fell in without any sensible inequality." Bird's manual skill and the great care he took to avoid errors arising from the partial expansion of the quadrant or tools during the operation gained him great and merited reputation, but we are inclined to doubt whether in engineering or theoretical accuracy of division he made any step beyond Graham. The careful division into 90° is a retrograde step.

The divisions of Graham, Bird, Ramsden, and the elder Troughton, were all performed by the beam-compass, and in a great measure by touch; magnifying lenses were indeed applied to the points of the beam-compasses, but when an erroneous point is once made, the beam-compass naturally falls into it, and there is considerable trouble in rectifying the error. A French nobleman, the Duc de Chaulnes, after perfecting the micrometer microscope for reading off the divisions of astronomical instruments [CIRCLE], first showed how it might be used in actual dividing. He did not however follow Graham's rule and proceed by perpetual bisections; hence his method was neglected, although Ramsden saw the advantage of the micrometer microscope, and used it for reading off the divisions of his circles and theodolites. In this state the art was taken up by Edward Troughton, who by a happy combination of the principle of Graham, the Duc de Chaulnes' mode of reading off, and his own ingenuity, brought the division of astronomical instruments to its present state of perfection. We will suppose that a circle is to be divided originally. After the edge of the circle is very carefully turned upon its own centre, a small circular roller, 16 revolutions of which carry it exactly round the circle, is prepared and so fitted to the circle by a radial frame joining the two centres, that on turning the frame round the roller is also turned in an opposite direction by friction between the edges of the roller and circle. The roller is divided into 16 parts, and a microscope placed over the divisions, and as each division comes under the microscope, a fine round dot is marked upon the circle, which thus receives an approximate division into 256 (or 2^8) equal parts. Troughton expected that as the roller could be carried round the circle by any number of times without over or under lapping, it would also mark out equal portions at each revolution, but he found himself mistaken, and he therefore proceeded to examine the dots optically. Two microscopes A and B are fixed above the circle, nearly in a diameter, and the dots which are to determine the divisions 0° and 180° are bisected by them. The circle is then turned half round, and dot 180° brought under A; if 0° at the same time falls exactly under B, the points are diametrically opposite, if not, the quantity and direction of the error is measured by the micrometer of B, half of which is evidently the error of dot 180°. The microscope B is then shifted and fixed over dot 90°, while A bisects 0°. By a quarter revolution of the circle 90° is brought under A, and 180° under B, and the error, if any, measured and noted. In like manner the error of dot 270° is detected, after which the microscope B is again shifted, and fixed over dot 45°, when the errors of dots 45°, 135°, 225°, and 315°, are determined. It is easily seen that this is exactly Graham's principle of perpetual bisection, only using an *optical* beam-compass instead of one without points, and *registering* the errors of the dots instead of cutting actual divisions. In this way Troughton proceeded by continual bisections to note the relative or apparent errors of the 256 dots. His next step was to compute the actual or true error of each dot, and to form a table. Suppose that in examining the 180° dot, he found that the arc from 0° to 180° was less than the arc from 180° to 360° by 20″, he would conclude that the dot 180° was 10″ behind its true place. Again, let arc from dot 0° to dot 90° exceed the arc from dot 90° to dot 180° by 30″. If 180° were right, 90° would be too forward by 15″; but as 180° is 10″ behind its true ptace, 90° will on this account alone be 5″ behind, and therefore on the whole will be 10″ too forward.* The true errors of each of the 256 dots being thus computed, Troughton returned to the roller, and by help of a small sector which revolved with it and gave him an enlarged scale, enabling him at the same time to reduce the division into 256 parts into 360° mechanically, proceeded to cut the actual divisions on the circle. This method was communicated to the Royal Society, and printed in the 'Phil. Trans. for 1809,' p. 105. The Copley medal was granted for this very valuable and original memoir. Several circles have since been divided after Troughton's method, by his successor Mr. Simms, and by Mr. Thomas Jones, and it has been thus proved that the merit of Troughton's dividing depended, as he asserted, on the excellency of his processes, and not on his manual dexterity. It is not worth while to divide a circle *originally* which is less than two feet in diameter.

There is a caution with respect to this mode of dividing which will be sufficiently obvious when pointed out,—namely, that very great care indeed must be taken that the pivots on which the circle turns shall be perfectly true and round. The circular line to be divided, and the rim on which the roller moves, are respectively drawn and turned from these pivots, and the figure of neither is a circle unless the pivots be so. The large collar of the mural circle on which the rim is turned is of steel, and several inches in diameter. It often happens that hard knots occur in the steel which ordinary tools will not touch, and it would be prudent in the artist to perform the finishing part himself with a diamond.

We should also recommend the following extension of Troughton's mode of examining his primary dots: After determining the errors of dots 0° and 180°, we should leave the microscopes A and B undisturbed, and fix two new microscopes, C and D, at 90° and 270°. Then, having adjusted C and D in 90° and 270°, and having ascertained their errors, as has been already described, the circle should be turned round till 0° and 180° are bisected by B and A, when 90° is under D and 270° under C. The errors are then to be again determined exactly as before. Now, if the circle turn round a mathematical point, the two results must, of course, be identical; but if not, it may happen that the observations will give two errors for dot 90° and two for dot 270°, which should, however, have the same difference. The final error, or that which the artist should adopt, for each dot, is the *mean* of the two determinations, which will give the position of a line at right angles to the diameter from 0° to 180°, and the nearest possible to the variable centre. It is also clear when this discrepancy is found that the centre has not been properly turned. By extending the above process to the dots which bisect the quadrants,—that is, shifting the microscopes C and D to 45° and 225°,—and trying the dots, as in Troughton's method, and also after a half-revolution, a series of bisecting diameters may be found which will cut the diameters already determined at angles of 45°, and pass as near the variable centre as may be. This process should be continued one or two steps more, and then Troughton's method may be considered sufficient for the rest. If the above system of examination should appear too troublesome, it would be at least advisable, when Troughton's subdivision has been carried to 16 or 32 parts, that the table of true errors should be checked by opposite readings. This is easily done by bringing each dot in its turn under microscope A, and reading off the apparent error of the opposite dot by microscope B. As the true error of the dot under A is known from the table of errors, this, + the apparent error as shown by B, should = the true error of the dot under B, which is also known from the table of errors. Any sensible discrepancy in these two values will show a faultiness in the centre. Again, if the artist have, as he ought to have, a convenient pier and a sufficiency of micrometer microscopes, he may ascertain the errors of his four or eight primary dots, by placing four or eight equidistant microscopes round his circle, and reading off at each quarter or one eighth of a revolution. It would be prudent to repeat this several times and on several days, selecting the times when the temperature had been and promised to be steady. This principle might be carried on farther in examining a graduated circle by changing the number of microscopes. Indeed, if the centre were very irregular, and therefore the curve traced out by its revolution, a better division into equal parts might be got after a preliminary division by *stepping* than by Troughton's method unaltered. As the + and − signs used in forming the tables of apparent and true errors may cause a little confusion, it is usual to cut a few slight divisions, which may easily be rubbed out, and thus to *test* the accuracy of the table of errors before commencing the actual division.

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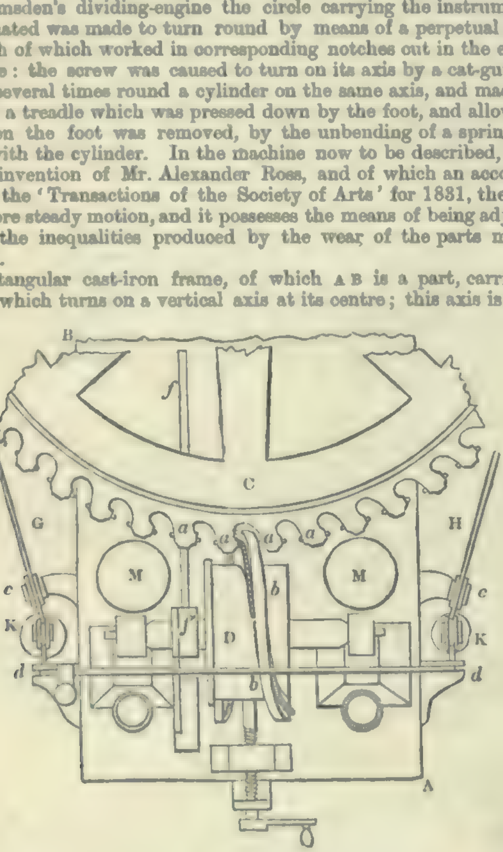
* Let ι and ι' be the errors of any two dots, a and b, + when too forward, and − when behind their true place, and the distance to the bisecting dot c be from $a = m$ and from $b = m + k$: then the apparent error of c is $-\frac{k}{2}$; for it should be at a distance $m + \frac{k}{2}$ from a. But the dot a is wrong ι, and the dot b is wrong ι'; therefore there is a further correction of $\frac{\iota+\iota'}{2}$, and the whole error of c is (attention being paid to the signs) $\frac{\iota+\iota'}{2}\ \frac{k}{2}$; from which expression the mode of forming the table of real errors is very evident, care being taken not to confound the signs, and also to pass from the arcs to the half arcs in succession.

It is easy to see how Bird's method of dividing a scale may be pursued, adopting microscopes instead of the beam-compass. The examination of such a scale is completely exemplified in Mr. Baily's memoir referred to in the sequel.

In Ramsden's dividing-engine the circle carrying the instrument to be graduated was made to turn round by means of a perpetual screw, the teeth of which worked in corresponding notches cut in the edge of the circle: the screw was caused to turn on its axis by a cat-gut band passing several times round a cylinder on the same axis, and made fast below to a treadle which was pressed down by the foot, and allowed to rise, when the foot was removed, by the unbending of a spring connected with the cylinder. In the machine now to be described, which was the invention of Mr. Alexander Ross, and of which an account is given in the 'Transactions of the Society of Arts' for 1831, the circle has a more steady motion, and it possesses the means of being adjusted, so that the inequalities produced by the wear of the parts may be obviated.

A rectangular cast-iron frame, of which A B is a part, carries the circle C, which turns on a vertical axis at its centre; this axis is in the form of two frustums of cones, and its lower extremity rests in a cup which is at one end of a lever; at the other end is applied a counterpoise which, causing a pressure upwards on the axis, diminishes the pressure of the circle on the frame which supports it. Round the circumference of the circle are 48 projections, *a*, *a*, *a*, &c.; and at one end (A) of the rectangular frame, a sliding apparatus carries a cylinder D, which turns on a horizontal axis, and has on its convex surface a spiral projection (*b b*) like a rectangular thread of a screw; this enters between the projections *a*, *a*, &c., and the distance between the two turns of the spiral is rather greater than the breadth of one of those projections.



On the rim of the circle C, and under the projections *a a*, &c., is a groove in which enters an endless cat-gut band, G H; on each side of the frame, at the end A of the latter, this band passes over a fixed pulley, *c*, and under a moveable pulley, from which is suspended a weight, K: it then passes through a notch at *d*, and above the frame, in the direction *d d*.

Four pillars, of which M M are two, rising from the rectangular frame A B, support a stage which carries the tool for cutting the divisions on the instrument to be graduated: the apparatus by which the cutting-tool is connected with the stage is formed with joints so as to allow the tool to be moved up or down, or in the direction of a radius of the circle C, but neither to the right nor left of that radius; and there is a contrivance for determining the length of the lines of division.

By moving one end of a lever at the opposite extremity of the frame A B, a bar, *f f′*, which is attached at one end to that lever, gives motion to a catch, or click, so as to cause a ratchet-wheel to turn on its axis, and thus give the requisite movement to the cutting-tool: the other extremity, *f*, of the bar, by turning a lever on a horizontal axle containing within it the axle of the cylinder D, allows a catch, or click, to turn a ratchet-wheel on the latter axle, and, with it, the cylinder itself; and thus a side of the spiral projection *b b* is removed a little way from its position when in contact with one side of a projection *a*. Moving then the first-mentioned lever back again, a spring, which had previously pressed against the cat-gut band on the circumference of C, is drawn off; and thus one of the weights, K, by drawing down the band and pulley above it, gives a small movement to the circle C, and consequently brings the side of a projection *a* again in contact with the side of the spiral. According to the place at which the bar *f f′* is applied to the lever on the axle of D, the catch may pass over any required number of the teeth of the ratchet-wheel; and thus the circle C may be turned through any angle consistently with the values of the divisions intended to be cut.

Through each of the projections *a a*, &c., passes a steel screw, whose ends appear in the above cut: and through the spiral thread *b b* pass a number of steel screws, whose ends also appear. The right-hand extremity (in the diagram) of each of the former screws is ground quite flat and perpendicular to the length of the screw; while the left-hand extremities of the screws in *b b* are turned in the form of hemispheres; and, after every movement of the circle C and of the spiral *b b*, the machine is held in a state of rest by the abutment of the hemispherical end of one screw against the flat end of the other.

The original divisions on the circle C are made on silver studs let into its surface; and the screws passing through *a*, *a*, &c., are so adjusted, by means of their capstan heads, that if the end of a screw in *b b* is in contact with the screw in any one of the projections *a*, one complete revolution of the spiral *b b* may bring the end of the screw in the next projection *a* in contact with the same screw in the spiral. The corresponding movement in the circle is equivalent to the interval between two of the original graduations; and the movement is verified by the primitive divisions coming successively to a wire in a microscope.

It may be useful, before we give a list of references for the history and practice of graduation, to point out the effect of excentricity in engine-divided circles, which is almost always mistaken for bad dividing by unskilful persons. If the centre of the divided circle is not concentric with the axis of rotation (we here suppose the circle to revolve, and the verniers or microscopes to be fixed), it is clear that the centre of the divisions will describe a very small circle about the axis. Now, suppose we set out from the position when the centre of the divisions is in a line with and between the axis and the reading apparatus. On turning the circle a little round, it will be seen that the angle through which the instrument *really* moves is less than the angle read off at that vernier or microscope; and on drawing the figure it will be seen that the angle read off is the exterior angle of a triangle of which the true angle is the interior and opposite; and also that the error or the difference between these two angles is the other interior angle of the triangle, the measuring arc of which to the same radius is, as to sense, equal to a perpendicular from the centre of divisions on the primary line.* Hence the error caused in any vernier by *excentricity* is an arc equal to the distance between the two centres × sine of the angle from the position we have set out from. From this consideration it will be evident to one who knows the nature of trigonometrical lines, that two, three, or any number of equidistant readings will cure excentricity, as the + errors must always equal the − errors. Now, if the possessor of a circular instrument having

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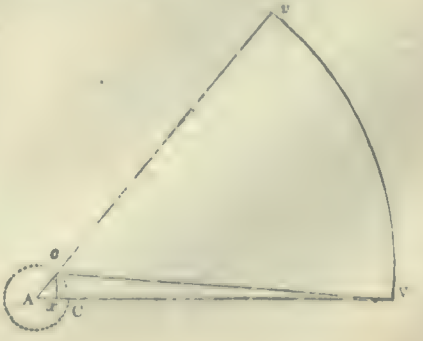
* Let A be the axis of rotation, C c the circle described by the centre of the divided circle V v V the place of the reading. In the position first mentioned in the text, *c* coincides with C, and *v* with V. When the instrument has been moved round the angle V A *v*, the angle *read off* is V *v* or V *c v*, and the error is the angle A V *c*, which is $\frac{cx}{cV} = \frac{Ac}{AV} \times \sin VAc$.



two or more equidistant readings wishes to examine the divisions, he may get rid of the effect of excentricity thus :—Take the mean of the readings at every 10°, 20°, or 30°, and subtract each reading from the mean. It will be seen whether the differences thus obtained can be represented under the form of a constant quantity $+x'' \times \sin.\ \theta$, where θ is reckoned from some definite point. If they can, there is no error of division, and the residual quantities, when the above equation has been satisfied in the best practicable manner, will give some insight into the quality of the divisions. The error which arises from the original circular form changing to an ellipse by a fall or other injury is of the form $y'' \times \sin.\ 2\phi$, where ϕ is the angle from some definite point of the divisions. Hence two readings at right angles, or three equidistant readings, will compensate each other; so that three or more equidistant readings will destroy the effect of both excentricity and ellipticity. In like manner the effect of any error which obeys a law may be investigated, when the law is known, and also the number of microscopes. Hitherto four or six microscopes seem to have made every circle a well-divided one.

The mode of reading the parts of larger divisions has been partly explained in the description of the microscope, article CIRCLE [ASTRONOMICAL], and will be finished under the head VERNIER.

The principal sources of information on this subject are :—'The Method of Dividing Astronomical Instruments,' by Mr. John Bird. London, 1767. 'Nouvelle Méthode pour diviser les Instruments de Mathématique et d'Astronomie,' par M. le Duc de Chaulnes, 1768. 'Description of an Engine for dividing Mathematical Instruments,' by Mr. J. Ramsden. London, 1777. Troughton's Memoir, 'Phil. Trans., 1809, p. 105. Graduation, 'Edinburgh Cyclopædia.' This very valuable article is by Troughton. 'On the Errors of the Cape Mural Circle,' by Messrs. Sheepshanks and Airy, 'Memoirs Royal Astronomical Society,' vol. v., p. 325. 'On the Cape Mural Circle,' by Professor Henderson, 'Memoirs Royal Astronomical Society,' vol. viii., p. 141. 'Description of the Mural Circle of the Armagh Observatory,' by Dr. Robinson, 'Memoirs Royal Astronomical Society,' vol. ix., p. 17. 'Report on the Standard Scale of the Royal Astronomical Society,' by Mr. F. Baily, 'Memoirs Royal Astronomical Society,' vol. ix., p. 35. In the Introductions to the 'Cambridge Observations' for 1833-4-5, and the Introduction to the 'Greenwich Observations' for 1836, will be found several instances of the way of examining the divisions of astronomical circles. See also article CIRCLE, and the references there given.

GRAFTING is an operation by which a portion of one individual of the vegetable kingdom is applied to another which is within certain limits of physiological affinity, so as to form a vital union, and consequently produce a reciprocal growth. Thus a species bearing small and austere fruit may be cut down, and the remaining part grafted with a scion from a tree of which the fruit is large and delicious; and being nourished, but not changed in any essential character, this scion will form a tree, ultimately producing fruit similar in every respect, all other circumstances being the same, to that of the tree from which it was taken. The shoots of any particular variety may be cut into many hundred pieces, if sufficiently numerous, and, by grafting, each of them can be made to possess all the properties of an individual tree in the course of one season. In the case of cultivated fruits, as well as in many varieties of ornamental plants, multiplication by seeds is precarious; and with regard to *hybrids* it is impracticable, at least no assurance can be had of a reproduction of the same variety; on the contrary, a disposition is generally manifested to return to the natural wild state of the species. Grafting is in some instances the only means, and in many it is the most eligible, of preventing this. By it the peculiar richness of the fruit or the delicate tint of the flower which we especially prefer and admire can be perpetuated in an almost infinite series of individuals, each being the result of augmentation of the comparatively small original portion—this portion being placed in favourable circumstances for receiving an abundant supply of new and proper matter, on which it exercises its organising powers, and effects a perfect assimilation, which causes a similar development of leaves, flowers, and fruit. Again, this newly-formed augmentation being every way similar to that from which it was derived, it will continue to exercise the same functions with regard to such new matter as comes within the extending scope of its organising powers, the progress only becoming arrested by such causes as naturally limit the growth of the parent tree. Propagation by cuttings, it is true, will equally continue the variety unchanged; but that process in numerous instances is slow: in others success is not attainable to any considerable extent.

From what has been stated, the great importance and utility of the process about to be explained will be sufficiently evident.

The limits within which grafting may be effected extend to species and varieties of the same genus, or at all events are confined within the same natural order. Pears may be grafted not only on other pears, but also on the quince (which is very frequently done), and on the medlar, white thorn, or mountain ash. Peaches are budded either on the almond, or more frequently on the plum, their own roots not being suited to the cold soil of this country. In these cases, although the leaves and fruit of the peach and the plum, the pear and the mountain ash, have a very different appearance, yet botanists have determined that the stock and the scion belong to the same natural order.

As one species is often grafted on another of a different genus, it is necessary therefore to state the reason why such is in many cases more proper than on species of the same genus; and this leads to the consideration of the effects generally produced by the stock upon the graft. When the stock is of slower growth than the graft, as in the case of the white thorn and quince stocks and the pear, the consequence is a partial obstruction of the flow of the sap, which checks the over-luxuriance of the pear-tree, and its natural disposition to produce only wood for a number of years of its youth; the juices, rendered less abundant, become more inspissated, and fruitfulness is induced at an earlier age. This condition may be even carried too far; for the common quince increases so slowly in diameter compared with the generality of pears, that its vessels become inadequate for a sufficient supply of nourishment. The French, aware of this, employ the Portugal quince as a stock for their pears, because its wood increases more in accordance with that of the latter. On the same principle (that is to say, a less copious supply of nourishment) trees are rendered more dwarf than they naturally are, and hence are better adapted for small spaces. On the contrary, a weak species will have a tendency to grow stronger if grafted on one naturally more vigorous. These are modifications induced by the stock on the graft extremely necessary to be known and attended to: for instance, apple-trees on crab-stocks, if injudiciously planted in a small garden, will soon overgrow their limits; whereas on the French paradise stock, the dwarfest of any, they are easily managed within a very small space; besides, the roots of the latter are very fibrous, and run near the surface, which renders them eligible for planting over a bad subsoil. Many species and varieties both of fruits and ornamental plants, natives of a warmer soil, are advantageously grafted on their hardier congeners, such as the peach and apricot on the plum, Chinese tender roses on the wild roses of our hedges, and many ornamental species of Cratægus on the C. Oxyacantha.

The methods of grafting are of great variety. M. Thouin ('Monographie des Greffes') has enumerated 43 modes of grafting, 39 of inarching, and 28 of budding. Many of these are however more curious than useful; and not worth being detailed. It will be better to explain the principle on which all modes of successful practice must depend, either as regards grafting, budding, or inarching.

It is well known that the bud of a plant has the power of becoming a distinct individual, if separated from the parent and placed in circumstances sufficiently favourable for its future development. But no development can take place unless the portion abstracted from any plant contain either a bud, or the perfectly formed rudiments of one. Hence the portion intended to be propagated must contain a bud or buds. The diametrical increase of exogenous plants proceeds outwardly, in consequence of the formation of new layers of alburnum, interwoven into the peculiar texture of the tree by extensions of the medullary rays. The alburnum is interposed between the inner bark and the heartwood, with both of which it is in vital or organised union. The greater part of the heartwood of a tree may be bored out, and, though made a hollow cylinder, it will still continue to increase. The outer bark may be removed, and a new one will gradually be formed; but, if the alburnum be entirely destroyed, death will be the consequence.

It appears therefore that buds with some portion of alburnum are the parts essentially necessary for propagation; for although the heartwood and bark be organised, yet they are but passively so, and have not the power of extending organisation to new matter when they are deprived of the media of buds and alburnum. Keeping therefore the importance of the latter in view, the best mode of operation is that whereby the greatest possible extent of the alburnum of the stock and graft is brought into exact contact, without making too extensive a wound. If the sections of alburnum can be made to coincide in every point, the result of the operation will be the most perfect that can be obtained.

The modes of grafting most generally practised are whip, cleft, saddle, and crown grafting. Of these *whip-grafting* is by far the commonest, and is performed as follows :—the stock is cut over, sloping, above a smooth and straight part. The end of the scion is cut sloping and thin towards the lower end. Then on the same side of the stock as that of the lowest part of the slope made in cutting off its top, a slice is cut clean off, in length equal to that of the cut part of the scion, and in breadth so as to expose as much of the wood of the stock as will equal that seen in the slanting section of the scion. Both sections should be smooth and plain, and as regards the alburnum, they should be the exact counterparts of each other; or, if this cannot generally be the case, the coincidence should be as exact as can be on one side at least. A thin wedge-shaped tongue is made very near the upper part of the slope in the scion, and a corresponding nick in the stock to receive it. The top part of the scion is shortened to two or at most three buds, and fitted to the stock, to which it is tied with a strip of pliable matting; and the parts so united are then covered with grafting-clay, or some other composition, which remains till the graft has pushed, or as long as there is no danger of the matting, used as a ligature, cutting or galling the parts when they begin to grow and to have an enlarged circumference. After the first loosening it is often advisable to apply slightly a fresh bandage immediately; and in some cases a little clay or composition may be put round, should the union appear too tender to endure exposure to the vicissitudes of the weather.

Cleft-grafting is performed by splitting the stock diametrically across the top, which should be cut horizontally, and then nicely inserting in one side a scion cut like a wedge. This mode is objectionable, because the deposition of young wood takes place for the most part in a projection exterior to the circumference of a circle having for its centre the axis of the stock; the top of the latter is consequently left long uncovered and becomes unsound from the wood being split to admit the graft.

Saddle-grafting is the reverse of the preceding, inasmuch as the stock, instead of the scion, is formed like a wedge; and the end of the scion made to fit over it, like a saddle. It is preferable to cleft-grafting, particularly where the stocks are small, or nearly of the same size as the scion; but when the stocks are large, it is by no means to be recommended.

Crown-grafting is performed on large limbs with thick bark, or on large stems; in either case these are cut off at right angles; the bark is raised by thrusting in a tapering flattened piece of smooth hard wood, or ivory, between the wood and bark; this being withdrawn, the end of the scion, properly thinned as if for whip-grafting, but without the tongue, is inserted. Three or four scions may with propriety be thus inserted in the same branch or stem. This method is objectionable for the following reasons: the section of the scion is plane; the part of the stock to which it is appled is circular; consequently, these surfaces can only come into partial contact. Again the abrasion must be considerably larger than the space covered by the scion, particularly if the bark of the stock be rigid. If we compare this state with the principle laid down in the preceding part of this article, the result will be, what ample experience has proved to be the case, that even on large trees whip-grafting is preferable. In fact, the cavity on each side of the scion in crown-grafting must be filled with something; either air, which is injurious, or if the tree be vigorous, a deluge of sap will flow to it; and it often happens that this, technically speaking, drowns the graft.

Cuttings intended for scions should be taken from the trees before the movement of the sap commences in spring, and put in moderately moist earth or sand, and out of the sun's rays. If the stocks be cut down at the same time it will be so much the better; any large limbs of trees which it may be found necessary to graft should by all means be cut in before vegetation becomes active, otherwise extravasation takes place and canker is in consequence induced.

Grafting Clay may be made from any smooth clay, or adhesive clayey yellow loam, or brick-earth, mixed with one-third, or, according to some, one-half of cow-dung, free from litter, excepting that of hay, and if it contain none of the latter, some fine hay must be beaten up with the mixture; the hay answers the same purpose as hair in plaster. A mixture of clay and horse-dung is preferred by some. The fact is, that any composition will answer that will exclude the air, retain some degree of moisture, and at the same time prove not injurious to the barks of the stock and scion which it surrounds.

Grafting Wax, a compound of pitch, rosin, bees'-wax, hogs'-lard, and turpentine, has had a great reputation as a means of fixing the scion to the stock, but it is liable to two serious objections. In the first place it does not adhere and exclude air unless both stock and scion are perfectly dry when it is used; secondly, the winds in March, the general period of grafting, are excessively drying, and were it not for the moisture absorbed from the clay the scion would frequently be shrivelled, and dried up before it had time to vegetate; but resinous substances do not permit of any similar absorption of beneficial moisture.

Inarching is a species of grafting, the success of which depends on the principles above explained. It is sometimes called grafting by approach, because in performing the operation the branches or stems of two contiguously growing plants are made to approach and unite; and this union is effected on the same principles as that of whip-grafting. Corresponding slices are taken off, a small slit being made upwards in the part that is to form the head, and another correspondingly downwards in the stock; being joined, the wounded parts are tied together, and covered with moss or grafting-clay. When properly united, that which is to form the top is by degrees severed from its parent root, and thus transferred it ultimately becomes the sole ascending stem of the one to which it was made to unite.

It is generally believed that although the stock and scion are organically united by the operation of grafting, yet no other effect follows the operation than what may arise from the slowness or quickness with which the stock allows the sap to rise upwards into the scion; and it is generally believed that the scion exercises no influence whatever upon the stock. It is however perfectly certain that a bud of a variegated jasmine, made to grow upon one branch of a large tree of a plain jasmine, will gradually give the variegated appearance to the plain stock. This was long since asserted, then denied, but has been since proved to be true by new experiments.

GRAIN (*granum*, a seed), an old measure of weight, the smallest of those in use. It is of about the weight of a seed of wheat corn, and must therefore be considered rather as a theoretical aliquot part of a larger weight, than as itself a proper standard of weight. We shall therefore refer to Weights and Measures, Avoirdupois, Troy, &c., for further information, stating in the present article all that refers to this particular measure. The word has not only designated a weight, but a coin. Ducange mentions an ancient Neapolitan piece of money called a grain, and the *grano* is still used in reckoning in Naples, Sicily, and Malta, though there are not now any coins so called.

By a statute passed in the reign of Edward III. (1266), it was enacted that 32 grains of wheat taken out of the middle of the ear, and well dried, should weigh a pennyweight, of which 20 should make an ounce, of which 12 should make a pound. Consequently the pound (troy), of this period consisted of 7680 grains, whereas that afterwards in use had only 5760. The reason was, that it became usual to divide the same pennyweight into 24 instead of 32 grains. This must have occasioned an alteration either in the value of the pound or of the grain. The former has been sometimes stated, but we believe the latter. The value of the average grain of wheat is stated by Paucton at ·86 of the grain of the *poids de marc*, that is, at about seven-tenths of our modern English grain. But if 32 grains of real weight were made to weigh 24 grains so called, the grain of wheat would be ·75 of the weight called a grain; which comes near the preceding. It is certainly possible that the grain of French wheat may differ from that of the English; and it is also known that the weight of grain varies considerably in different harvests and under different modes of culture. This latter circumstance rather affords a presumption that it was the wheat which varied: it is not at all unlikely that improved agriculture gave wheat of which 24 grains were equivalent to 32 of the more ancient harvests. According to Dr. Bernard's measurement, the grain of barley is ⅔, or ·67 of the troy grain.

However this may be, the grain must have lost much of its importance by the introduction of the avoirdupois pound, of which it is not a constituent aliquot part. The ancient avoirdupois pound is variously stated at from 7009 grains to less than 7000, at which latter number it is now fixed by law.

The grain has varied considerably in different countries: Dr. Bernard mentions the Rabbinical grain, which was two-thirds of the English grain; the money grain of Venice and Paris (that of the poids de marc above noticed), which he places at ·8334 of the English grain; and the physicians' grain of the Greeks, Arabs, and Venetians, which was ·9166 of the English grain.

The weight of one grain is obtained, for practical purposes, without difficulty, by weighing a thin plate of metal of uniform thickness, and cutting out by measurement such a proportion of the whole plate as should give one grain. But a much better plan is to draw a given weight of ductile metal into very thin wire, and to cut from the wire that length which is the same proportion of the whole length as a grain is of the whole weight. In this way pieces of wire are obtained for chemical purposes which weigh only the thousandth part of a grain; and even less weights might be obtained, if it were necessary.

GRAMMAR. [Language.]

GRAND JURY. [Jury.]

GRAND SERJEANTY, one of the ancient English tenures. The tenant, instead of rendering to the king pure military service, was bound to perform in person some special honorary service to the sovereign himself, as to carry his banner, or to be his butler, champion, or other officer at his coronation. It was in most other respects like knight service. Tenure by grand serjeanty still exists so far as relates to merely honorary services, but the burdensome incidents were taken away by the stat. 12 Car. II. c. 24.

GRANDEE. *Grande de España* is the name of the highest rank in the Spanish nobility. The grandees were originally the descendants of the great feudatories of the crown, but since the time of Don Carlos I. (Charles V. of Germany), who unceremoniously excluded them from the national assembly of the Cortes, it became the practice of the Spanish kings to raise new men to the rank of grandees, with the double object of rewarding their friends and at the same time breaking down the pride and influence of an order which was to them an object of jealousy. This occasioned a distinction between the old and new grandees, which was marked by the old ones addressing each other always in the second person singular, "thou," and by being addressed "excellenza," without distinction of age or official station; whilst they addressed on all occasions those of a recent creation by the title of "your excellency," which belongs to all Spanish grandees, with studied punctiliousness. The old grandees had the privilege of being covered in presence of the monarch; and now, the elevation to the rank of grandee is announced by the monarch desiring him to be covered. Few of the old families are now extant in a direct line.

All the grandees of Spain, and also the Titulos de Castilla, or marquises with a Castilian title, had a right to sit in the old Cortes whenever the king pleased to convoke them, and they did so sit in the Cortes assembled, in 1789, as the representatives of the estamento, or order of the nobility. The collective body of the grandees is called La Grandeza, but they have no political privileges under the present constitution, as there is no hereditary house of legislature at present in Spain. The titulos, or lower nobility, are excessively numerous, and are addressed as su señoria, abbreviated in common speech to ussia.

GRANT (Concessio), in law, is technically and strictly a conveyance in writing of incorporeal hereditaments, or of such interests in or arising out of land whereof no livery or actual tradition can be made.

All corporeal hereditaments, as lands and houses, of which actual delivery can be made, are said to lie in livery; but advowsons, commons, rents, reversions, &c., which from their nature cannot so be transferred, are said to lie in grant. This distinction has been removed by modern legislation, and a grant may now be made of every species of property. At common law, as at present, a writing was necessary to support a grant; the writing being the evidence of such transfer of property, as livery of seisin was in the case of a feoffment. Until the statute 4 Ann. c. 16, sc. 9, the ceremony of attornment was necessary in such grants of interests in reversion or remainder as are grantable; that is, the tenant in possession consented to the grant of the seignory, by which consent he became tenant to the new lord.

Attornment was a consequence of the feudal law, and until the ceremony was rendered unnecessary by the statute cited, and by another (11 George II., c. 19), the doctrine relating to it was one of the most confused and difficult branches of the law.

GRANULATION. [WOUND.]

GRAPE SHOT is an assemblage, in the form of a cylindrical column, of nine balls resting on a circular plate, the size of the bore of the gun, through which passes a pin serving as an axis. The balls are contained in a strong canvas bag, and are bound together or quilted on the exterior of the latter by a cord disposed about the column in the manner of a net; they then have something of the appearance of a bunch of grapes. From the rusting of the iron shot the canvas becomes soon destroyed, hence another description of grape shot, sometimes called tier shot, has been introduced; the balls are retained round the iron pin by a series of flat iron plates, screwed down parallel to the lower plate, and between every two of which is a layer of balls.

The dimensions of a column, or assemblage of balls, and the sizes of the balls in the column, vary from 4 lbs. to 8 oz. with the nature of the ordnance from which they are to be discharged; according to the present method the grape shot are adapted to 6, 9, 12, 18, 24, and 32-pounder guns, but their weights are rather greater than those of the usual shot which correspond to each nature of gun.

A fire of grape shot is on service frequently directed against an enemy's troops when advancing in close order to an attack, and on board ship at close quarters: 600 yards is considered the limit of the effective range of grape.

GRAPE SUGAR. [SUGAR.]

GRAPE VINE. [VINE.]

GRAPHIC ACID. [GRAPHOTE.]

GRAPHITE. *Plumbago. Black Lead.* The natural sources of this variety of carbon, and the uses to which it is applied, have already been described. See GRAPHITE, in NAT. HIST. DIV.

The artificial formation of graphite occurs in several manufacturing processes. For example, when cast-iron is melted in contact with charcoal, a quantity of the latter is dissolved, and on the cooling of the mass, crystallises out in characteristic six-sided plates; closely resembling that variety of graphite now largely imported from Ceylon. Crystalline graphite is also deposited in the retorts used in the manufacture of coal-gas. Amorphous graphite—similar to that obtained from the Borrowdale mines in Cumberland and from Germany—is deposited on one of the carbon terminals of the electric-light apparatus during the passage of the current.

For most of the useful purposes to which it is applied, graphite requires to be freed from the impurities with which, in the native state, it is nearly always contaminated. To this end, a process, discovered by Professor Brodie, has recently been made the subject of a patent. Its details are as follows:—One pound of powdered graphite is mixed with four pounds of concentrated sulphuric acid, and one ounce of powdered chlorate of potash is then added. The mixture is heated until chlorous fumes cease to be evolved, the residue is then thrown into water, washed, dried, and ignited. The ignited substance is washed in water, on which it floats, while the impurities fall to the bottom. Lastly, it is dried. By this process the graphite may be obtained in a state of chemical purity.

The phenomenon that ensues during the ignition of the substance just described is very peculiar, much resembling that which takes place on the application of heat to the bichromate of ammonia. Gases are given off in the interior of the little grains or plates, the whole swells up to very many times its original bulk, and is reduced to the most minute state of division.

According to Professor Brodie's researches, the composition of the body that results from the oxidation of graphite as above detailed, is not constant. It contains the elements of sulphuric acid combined with oxygen, with hydrogen, and with a large per centage of carbon. By repeating the oxidising process, however, five or six times, the whole of the graphite is converted into a light-yellow, transparent, crystalline substance, to which Professor Brodie has given the name *Graphic Acid.* It contains:—

Carbon	61·11
Hydrogen	1·85
Oxygen	37·04
	100·00

Corresponding with the formula $C_{22}H_4O_{10}$. Graphic acid is very slightly soluble in water, combines with the alkalies to form crystalline salts, and is reduced by deoxidising agents to a body resembling graphite.

GRASS LAND may be divided into water-meadows, upland pastures, and artificial grasses. The first are treated of under IRRIGATION: the nature and management of the two last we shall here briefly describe. Upland pastures are portions of land on which the natural grasses grow spontaneously, varying in quantity and quality with the soil and situation. The plants which form the natural sward are not confined to the family of the Gramineæ, but many other plants, chiefly with perennial roots, form part of the herbage. In the richest soils the variety is exceedingly great. When a sod is taken up, and all the plants on it are examined, the species will be found more numerous than we should have believed possible;[*] and in the same ground the plants will vary in different years, so as to induce one to conclude that, like most other herbaceous plants, the grasses degenerate when they have grown for a long time on the same spot, and that a kind of rotation is established by nature. It is chiefly in those pastures where the grasses are allowed to grow till they form their seed that this is observable; for when they are closely fed, and not allowed to shoot out a seed-stem, they are less subject to degenerate and disappear. This may be a reason why experienced dairymen are so unwilling to allow their best pastures to be mown for hay. They pretend that the feed is deteriorated in the next year, and that inferior grasses are introduced which injure the quality of their butter and cheese. Close feeding is always considered as the most advantageous, both to the cattle and the proprietor.

The only way in which a pasture can be profitable is by feeding stock; and its value is in the exact proportion to the number of sheep or cattle which can be fed upon it in a season. Extensive pastures are often measured only by their capacity in this respect. Thus, we speak of downs for 1000 sheep; and in Switzerland and other mountainous countries they talk of a mountain of 40, 60, or 100 cows, without any mention of extent in acres.

When a pasture is naturally rich, the only care required is to stock it judiciously, to move the cattle frequently from one spot to another (for which purpose inclosures well fenced are highly advantageous), and to eradicate certain plants which are useless or noxious, such as docks and thistles, furze, broom, briars and thorns, which, not being touched by the cattle as long as they have better food, would increase and overrun the ground, and take up a space which would be more profitably occupied by good herbage. The dung of the cattle also, when left in heaps as it is dropped, kills the grass and introduces coarse and less palatable plants. This must be carefully beat about and spread, or carried together in heaps to make composts with earth, to manure the poorer meadows or the arable land. All that is required in rich pastures in which cows and oxen are fed, and which are properly stocked, is to prevent the increase of the coarser and less nutritive plants. Weeding is as important in grass as in arable land; and if it is neglected, the consequence will soon be observed by the inferior quality of the feed. The urine of the cattle is the manure which chiefly keeps up the fertility of grass land; and although in hot and dry weather it frequently burns up the grass where it falls, when it is diluted by showers the improved appearance of the surface shows that its effect has not been detrimental. To enrich poor meadows there is no manure so effective as diluted urine, or the drainings of stables and dung-hills.

When pastures are poor, and the herbage is of a bad quality, the cause is to be sought for in the soil. A poor arid soil is not fitted for grass, nor one which is too wet from the abundance of springs and the want of outlet for the water. These defects can only be remedied by expensive improvements. A soil which is too dry may be improved by cultivation and judicious manuring; but for this purpose it must be broken up and treated for some time as arable land: and it may be a question whether or not the expense of improving the soil will be repaid by the superior quality of the pasture when it is again laid down to grass. In general the poor light soils, if they are worth cultivation, answer better as arable land, especially where the turnip husbandry is well understood. The low wet clay soils may be converted into good pastures by draining them well; and the improvement thus produced is so great, that judicious draining in such soils is the most profitable investment of capital.

When old meadows have been neglected, or too often mown, without being recruited by manure or irrigation, they are often overrun with moss or rushes, and produce nothing but a coarse sour grass. In that case, besides draining it if required, the land must be broken up and undergo a regular course of tillage, until the whole of the old sward is destroyed, and a better collection of grasses covers its surface. If this be done judiciously, the pasture will not only be greatly improved in the quality, but also in the quantity of the grass. There is a natural prejudice against the breaking up of old grass land. This has arisen from the improper manner in which it is frequently effected. The sward when rotten is a powerful manure, and produces great crops of corn. These tempt the farmer to repeat the sowing of corn on newly broken up lands. The fertility is reduced rapidly; and when grass seeds are sown after several crops of corn, the soil has been deprived of a great portion of the humus and vegetable matter which is essential to the growth of rich grass. The proper method of treating grass land, broken up to improve it, is to take no more corn crops than will pay the expense of breaking up, carting earth, lime, or other substances upon it, to improve the soil, and to lay it down to grass again as soon as the old sward is fully destroyed.

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[*] In a sod of grass taken from Selborne Common, the following grasses were found: *Plantago lanceolata, Agrostis capillaris, Avena flavescens, Dactylis glomerata, Festuca duriuscula, Poa annua, Cynosurus cristatus, Trifolium repens, Crepis tectorum, Achilea millefolium, Galium verum, Hypochæris radicata, Hieracium pilosella, Thymus serpyllum.* (Curtis 'On Grasses.')

If the soil is fit for turnips, no better crop can be sown to prepare for the grass seeds, which should be sown without a corn crop, except where the sun is powerful, and the seed is sown late in spring: but autumn is by far the best season for sowing grass seeds for permanent pasture. Turnips of an early kind may be sown in May, and fed off with sheep in August or September; and the ground being only very slightly ploughed, or rather scarified, and harrowed fine, the seeds may be sown and rolled in. The species of grasses sown must depend on the nature of the soil; but it is impossible to be too choice in the selection. That mixture of chaff and the half-ripe seeds of weeds, commonly called hay seeds, which is collected from the stable lofts, should be carefully rejected, and none but seeds ripened and collected on purpose should be sown. The *Trifolium repens* (white clover), the *Trifolium medium* (cow grass), *Medicago lupinula* (trefoil), *Lolium perenne* (rye grass), the poas and festucas, are the best kinds of grasses. A very easy way of obtaining good seed is to keep a piece of good meadow shut up from the cattle early in spring, carefully weeding out any coarse grasses, and letting the best arrive at full maturity; then mow and dry the crop, and thresh it out upon a cloth. This will give the best mixture of seeds; but some of the earliest will have been shed, and these should be collected separately, or purchased from the seedsmen. Before winter, the ground will already be covered with a fine green, if the seed has been plentiful. The quantity per acre of the mixed seeds should not be less than 30 or 40 pounds to insure a close pile the next year. If the soil is not naturally rich, liquid manure, or urine diluted with water, should be carried to the field in a water-cart, and the young grass watered with it. This will so invigorate the plants that they will strike and tiller abundantly.

The following are lists of seed proper for different soils, taken from Mr. Lawson's 'Agriculturist's Manual,' pp. 203, 4, 5, 6.

"In preparing grass seeds for sowing in mixture, it has been found that a reference to weight is more correct in practice than to measure; and for the sake of comparison, the tables, giving the average weight of a bushel of each kind of seed, are here inserted.

WEIGHT OF THE SEEDS OF GRASSES AND OTHER PLANTS, PER IMPERIAL BUSHEL.

	lbs.		lbs.
Agrostis stolonifera	13	Festuca tenuifolia	13
„ vulgaris	13	„ pratensis	12½
Aira flexuosa	6½	„ rubra	10
Alopecurus geniculatus	6	„ sylvatica	10½
„ pratensis	5½	Glyceria fluitans	14½
Arrhenatherum arenacerum	7	Poa glauca	7½
Anthoxanthum odoratum	6	„ nemoralis	18¾
Avena flavescens	5	„ pratensis	13¼
Briza media	10¼	„ trivialis	15¼
Cynosurus cristatus	26	Holcus lanatus	7
Dactylis glomerata	11½	Lolium perenne, the varieties vary from	18 to 30
Elymus arenarius	9½	„ italicum	16½
Festuca duriuscula	9¾	Phalaris arundinacea	48
„ elatior	20	Phelum pratense	44
„ heterophylla	12¼	Poa annua	14
„ loliacea	15	„ aquatica	18½
„ ovina	13½		

CLOVERS AND OTHER PLANTS.

	lbs.		lbs.
Achillea Millefolium	26¼	Trifolium pratense	62
Hedysarum Onobrychis	26	„ cow-grass	62
Lotus major	64	„ procumbens	64
Medicago lupulina	63¾	„ repens	65
Plantago lanceolata	51¼	Vicia sepum	65
Poterium Sanguisorba	24½	„ cracca	66
Trifolium minus	64½	„ sylvatica	64

"In sowing down grass lands *without a crop*, the benefit in hay or pasture is sooner acquired, without the soil being in any degree exhausted by a corn crop. In most cases, however, a greater quantity of seed is necessary, than where the young grass enjoys the protection and shelter afforded by a cereal crop. These advantages may in a great measure be gained in sowing down grass lands without a crop, and with a considerable saving of grass seeds, by sowing along with the mixture, a bushel of rye or of winter barley per acre, in autumn sowing, for shelter in winter; and a bushel of barley per acre for protecting the young plants from the scorching drought of summer, when sown in spring; observing that the barley or rye shall be eaten or cut down while in a green state.

"Although *Lolium italicum*, when sown in too great a proportion, from its strong habit of growth is apt to choke or weaken the clovers, yet by substituting 5 lb. of it for 8 lb. *Lolium perenne* in the above table, the produce will be materially improved.

QUANTITY OF GRASS SEED PER IMPERIAL ACRE.

I. *For Alternate Husbandry.*

	Light and Medium Soil.			Heavy Soils.		
	1 Year's Hay.	1 Year's Hay and 1 year's Pasture.	1 Year's Hay and 2 years' Pasture.	1 Year's Hay.	1 Year's Hay and 1 year's Pasture.	1 Year's Hay and 2 years' Pasture.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Lolium perenne	18	18	18	18	18	18
Phleum pratense	..	..	..	1	1	1
Trifolium pratense	8	6	3	8	6	3
„ „ perenne	..	..	3	..	..	3
„ repens	2	4	4	2	4	4
Medicago lupulina	..	2	2	..	2	2
	28	30	30	29	31	31

"In proportion to the tenacity and retentiveness of very heavy soils, *Phleum pratense* should be increased from ½ lb. to 1½ lb., additional, and in many cases, for one and two years' pasture, *Arrhenatheram arenaceum*, *Dactylis glomerata*, *Poa trivialis*, and some others, might be partly substituted for *Lolium perenne*, varying the kinds and quantities according to circumstances.

II.—1. *For Permanent Pasture.*

	Light Soils.		Medium Soils.		Heavy Soils.	
	With a crop.	Without a crop.	With a crop.	Without a crop.	With a crop.	Without a crop.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Alopecurus pratensis	1	1½	1½	2	2	2
Avena flavescens	½	½	..	..	..	..
Dactylis glomerata	4	5	4	5	4	5
Festuca duriuscula	2	2	2	2	1	1
„ heterophylla	..	..	1	1	1	1
„ loliacea	..	..	..	..	1	2
„ pratensis	1	2	3	3	2	3
„ rubra	2	2	..	..	..	..
Lolium perenne	10	12	10	12	10	12
Phleum pratensis	..	..	1	1½	2	3
Poa pratense	1	1	..	..	..	..
„ trivialis	..	..	2	2	2	3
Medicago lupulina	1	1	1	1	1	1
Trifolium pratense perenne	3	4	3	4	3	4
„ repens	4	5	4	5	4	5
And common barley or rye, about one bushel additional to such as are sown without a crop.	29½	36	31½	38½	33	42

II.—2. *For Permanent Pasture.*

	Light Soils.		Medium Soils.		Heavy Soils.	
	With a crop.	Without a crop.	With a crop.	Without a crop.	With a crop.	Without a crop.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Aira cæspitosa *lutescens*	..	..	1	1	1	1
Alopecurus pratensis	1	1½	1½	2	2	3
Arrhenatherum avenaceum	..	..	1	1½	2	2
Avena flavescens	1	1½	½	1	..	..
Dactylis glomerata	2	2	2	2	3	3
Festuca duriuscula	2	3	3	3	2	2
„ heterophylla	1	1	1	1	2	2
„ elatior	..	..	..	..	2	2
„ loliacea	..	..	1	1	2	3
„ pratensis	..	..	2	2	3	2
„ rubra	2	3	..	..	..	..
Lolium italicum	3	3	3	3	3	3
„ perenne	5	5	5	5	5	5
Phleum pratense	..	..	1	1½	2	2½
Poa nemoralis	2	3	3	4	2	3
„ pratensis	1	1	..	..	..	..
„ trivialis	..	..	1	1½	2	2½
Medicago lupulina	1	1	..	..	..	..
Trifolium pratense *perenne*	3	4	3	4	3	4
„ repens	4	5	4	5	4	5
Also barley, or rye, as in the last table.	28	34	33	38½	30	45

"The foregoing table (ii.—1.) is drawn out with a view to the strictest economy as regards the original outlay: yet by introducing 4 lb. *Lolium italicum* for 5 lb. *Lolium perenne*, the bulk of pasture will be increased, and the quality improved; and where the value of the seeds of *Lolium italicum* does not exceed three or four times those of *Lolium perenne*, a more profitable return upon the whole will be yielded by its introduction.

"The next table (ii.—2.) contains a greater proportion of the more rare and valuable sorts of seeds, although these will add considerably to the first expense, yet the improved produce will annually give a greater return; and to the mixture in both tables may be introduced with advantage, on dry and elevated sheep pastures, 2 lb. to 4 lb. of *Festuca ovina*; on dry light lands, ½ lb. *Achillea Millefolium*; on dry calcareous soils, 6 lb. to 10 lb. *Onobrychis sativus*; in some cases 1 lb. to 2 lb. of *Cichorium Intybus*; and 2 lb. *Apium petroselinum* on lands where sheep are subject to liver-rot; and in all cases when a crop of hay is intended to be taken the first year, 2 lb. *Lolium perenne*, 1 lb. *Lolium italicum*, and 2 lb. *Trifolium pratense* should be added."

In a recent volume of the English Agricultural Society's 'Journal,' some valuable information was given by Mr. Thompson, its editor, and Mr. Dixon, a Cheshire land agent and agriculturist, on the management and improvement of grass lands, of which we give the following account:—

Mr. Thompson's paper is more especially devoted to the consideration of the best method of treating newly laid down grass, in order to success in the production of a good permanent pasture. He states that, after long experience and repeated failures in the attempt to establish a pasture by folding sheep year after year on the young grass, he "became satisfied that to graze sheep on young seeds intended for permanent pasture was a mistake, and that in all probability it had been the cause of several previous failures. Up to that time," says Mr. Thompson, "I had never succeeded to my own satisfaction in laying down land to grass; but since making a rule rigidly to exclude sheep for some years from newly-laid grass during the season of active growth, I have never had a failure, though I have twice had occasion, for local reasons, to lay down fields of which the soil was strong clay. The method which I have found to answer best has been to sow a liberal allowance of the hay-seeds of the district, with a sprinkling of cow-grass and white clover; to sow them with a crop of wheat (one of the short-strawed varieties); to mow the first year, and as soon as the hay is removed, to give a good dressing of farm-yard manure, and then for some years pasture it with cattle, beginning for the first year or two with young stock, until the turf is close and strong enough to bear the treading of heavy cattle. If farm-yard manure is not to be had, 3 cwt. of best Peruvian guano per acre will prove a tolerable substitute, though by no means equal to the former. For some years a newly-laid pasture will, unless the land be of *very* superior quality, require assistance from time to time to keep it in an improving state: an occasional dressing of farm-yard manure is, of course, the best; but as this is rarely obtainable in sufficient quantity, it must be eked out by other means."

The following are among the more striking of the experiences of various top-dressings for pasture land recorded by Mr. Dixon:—

1. *On Boning alone.*—"A great improvement by bone manure was effected by Captain De Hollenworth, of Hollenworth Hall, Cheshire, between the years 1840 and 1843. In those three years about 1500*l.* was expended on bones, principally boiled, and about 4*l.* in value was used to the acre. Boiled bones at that time cost 4*l.* per ton; raw broken bones, 7*l.* per ton. The land where the manure was used is nearly 600 feet above the sea; old turf; the climate does not mature corn well: character of the soil varies, some peaty, on aluminous shale or stone; other parts a lightish gray soil, on aluminous slaty stone. It was on the latter description of soil that the bones effected the greatest change. The grass had sometimes been eaten off, and sometimes mown for hay. The quality of the herbage was totally changed within the first two years after boning. Some of the meadow land which had been let at 30*s.* per acre was readily raised to 3*l.*, and still made more money for the tenant when turned either to the feeding and breeding of sheep or the feeding of cattle. In the year 1841 Mr. Williamson, a tenant farmer residing at Huxley, near Tarporling, expended 374*l.* in bones, principally boiled. Mr. Williamson's farm is 50 miles south-west of Captain De Hollenworth's farm, and is 60 feet above the sea. The whole of the bones were applied to grass land, at a cost of 2*l.* 10*s.* per acre. Mr. Williamson's pasture land has a peculiarly close-textured soil and subsoil, approaching nearly to the lias clay, though brown-red in colour, and effervesces violently when tested with spirits of salts. Previous to boning, the herbage on these pastures was of the poorest kind imaginable, there being few if any plants except the small carex; in the second summer after boning the carex had disappeared, and the pasture had become long and thick-set with white clover, cow-grass or marl clover, and trefoil. The dairy stock had also been increased from 40 to 52 cows: the 40 cows had been at times almost starved; the 52 cows had abundance, and more than they could feed down, and sheep were purchased for the excess keep."

2. *On Boning with Drainage.*—"In the year 1838 I inspected a farm 28 miles west of Captain De Hollenworth's. The altitude of this was about 80 feet above the sea. Up to August in that year 250*l.* had been expended in boiled bones (cost 4*l.* per ton); the quantity applied to the acre was about 16 cwt., the soil and subsoil being much the same as on Mr. Williamson's farm; the herbage growing on it of the same kind, but apparently more scanty. Several small fields had not been dressed with the manure, nor had any stock been in these fields during the summer up to the month named. So little, however, was the herbage, that I computed that not more than 20 stones of hay could be obtained from an acre. In 1839 I again inspected this farm, and the pastures showed considerable improvement. The dairy stock on the farm the preceding year consisted of four cows, which had been increased to eight. It is proper to mention here, that the land in question had been in grass for a long series of years, its wetness and natural cohesiveness having been a bar to any attempt at converting it to tillage. The extent of the farm in question is 98 acres. In 1842 the dairy stock on this farm was 24 cows, and in the autumn of that year 80 sheep were put on the land to consume the superabundant grass on the pastures. In November, 1843, I again inspected this farm. The weather had been wet for some weeks, and I was sorry to see much good herbage on the land almost lost for want of the surface-water being properly carried off. Within the past two years I have been three times over this farm; it is still in a bad state from want of efficient drainage, and the bones seem to have lost much of their former effect."

3. *On Liming.*—"In the year 1845 a gentleman purchased several hundred acres of land in small farms, all lying in a district of country about 600 feet above the level of the sea, neither the land nor its occupants being in a position to help one another. But the gentleman wishing to see the land of his early days wear a more pleasing appearance, even at great cost, the thing was to be attempted. It was almost to an acre old grass land, as corn at that elevation will not often reach maturity. I was engaged to direct the re-modelling of the fields, and the manuring of nearly all the property. Most of the soil lay on poor clay or shale, and lime was used to a great extent. Rather extensive draining was done on the clay land; and the material thrown out of the drains being of a soft and very cohesive character, we did not return it into the drains. It was mixed with lime; and our object being to destroy or reduce the nature of the clay, we put clay and lime together in about equal bulk: the lime nearly burnt the clay; to do that about 14 days were required. The compost was then turned over altogether in a powdery state. In due course it was applied to the land, and in a few weeks there was ample evidence that the practice was correct. The compost acted sooner than lime alone would have done; it has been *equally*, or, I might say, to some extent *more* effective. About 1000 tons of lime have been used on these small farms, at the rate of 8 or 9 tons to the acre, and a great improvement brought about. The lime costs here 12*s.* per ton. It was brought 30 miles by water, and 2½ miles by carts. In one year after the lime had been applied, 10*s.* to 15*s.* per acre advance in rent was readily obtained. Bones have been used here to a limited extent, but, unless applied in double the quantity sufficient for most lands in low altitudes, the change is not satisfactory."

In some soils which are not congenial to grass the seed does not take so well as in others; and there is a great difficulty in producing a good sward. In this case recourse may be had to planting, or, as some call it, inoculating grass. This is done by taking pieces of sward from an old meadow, and spreading them over the surface of the land to be laid down, after it has been ploughed and prepared in the same manner as it would be to receive the seed. The turf of the old meadow is taken up with a peculiar instrument in strips two inches wide and these strips are cut across so as to form little square pieces, which are spread over the ground, leaving about five or six inches of interval between every two pieces. The heavy roller presses them into the ground. These tufts soon spread and fill up all the intervals with a complete old sward. This is a very effectual and certain method of producing a permanent pasture. Some attention is required to prevent weeds in the intervals between the tufts at first: by going over the field with a narrow hoe, all weeds may be easily kept down; and the roots and tillers of the grass soon fill up the vacant spaces.

The fertility produced by grass which is fed by cattle and sheep has given rise to the practice of converting arable land to pasture for a certain time in order to recruit its strength. The old notion was that the land had *rest*, which by a confusion of ideas was associated with the rest of the labourers and the horses. Ploughing was called working the land; and some men talked of working out the heart of the land by ploughing. That the ploughing of land does not diminish the productive power of all soils that are fit for cultivation, will be readily allowed. The sea sand no doubt, where a few bents have taken root, would not be improved by being stirred; neither would very light soils under a burning sun: but in our moist climate there is seldom any danger of over-ploughing. The land, by being in grass, has much vegetable matter added to it from the fibres of the roots which die and decay, as well as from the other parts of the grass, which draw nourishment from the atmosphere and impart it to the roots. Thus in time an accumulation of vegetable soil is formed; and when the land is ploughed the rotting of the sward greatly increases it. Every species of plant thrives well in this improved soil; and the vigour of the growth is ascribed to the recruiting effects of rest, by a fancied analogy with the animal muscle, which is invigorated by occasional inaction.

But setting aside theory, it is well known that land which has been some years in grass is improved in fertility. The convertible system of husbandry takes advantage of this fact; and all its art consists in reproducing a good pasture without loss of time, after having reaped the benefit of the fertility imparted to the land during three or four years when it was in grass. Good pasture is very profitable; so are good crops: by making the one subservient to the other, the farmer who adopts the convertible system is enabled to pay higher rents, and still have a better profit than those who adhere to a simple rotation of annual crops.

When an arable field is sown with the seeds of grasses and other plants which give herbage for cattle, it is called an artificial meadow, and the various plants which are raised are all called artificial grasses, although many of them have no botanical title to the name of grass, such as clover, saintfoin, lucern, and many others, which produce the best pastures and the finest hay.

In laying down a field to grass for a very few years the mode of proceeding is somewhat different from that which is recommended for producing a permanent pasture. Clover in this case is always a principal plant, both the red and the white; these with annual or perennial rye grass are sown with a crop of corn in spring, and begin to show themselves before harvest. The grasses are often mown the first year after they are sown, on account of the abundance and value of the red clover, but the best farmers recommend the depasturing them with sheep, to strengthen the roots and increase the bulk. Various circumstances, such as a greater demand for clover hay, or for fat cattle, may make mowing or feeding most profitable; but when there is not a decided advantage in making hay, feeding should always be preferred. At all events the great object of the farmer should be to have his land in good heart and tilth, and free from weeds, when the grass is sown. If his grass is good, he is certain of good crops after it with little trouble or manure.

The seeds usually sown on an acre, when the land is laid down to grass, are as follows:—Red clover, 12 lb.; white, 6 lb.; trefoil, 4lb.; rib grass, 2 lb.; and 2 pecks of Pacey's rye grass. Sometimes cockfoot grass (*Dactylis glomerata*) and cow grass (*Trifolium medium*) are added. This is for a field intended to remain four or five years in grass.

The introduction of artificial meadows, in districts where the soil seemed not well adapted for pasture, has greatly increased the number of cattle and sheep reared and fattened, and has caused greater attention to be paid to the means of improving the breeds of both. Thus a double advantage has arisen: the public is benefited by an increased supply, and the farmer is rewarded by an additional source of profit.

In the neighbourhood of large towns there are many meadows, which, without being irrigated, are mown every year, and only fed between hay harvest and the next spring. These require frequent manuring to keep them in heart, and with this assistance they produce great crops of hay every year. The management of this grass land is well understood in Middlesex. Sometimes the meadows are manured with stable dung which has been laid in a heap for some time, and been turned over to rot it equally. This is put on soon after the hay is cut, and the rains of July wash the dung into the ground; but if a very dry and hot summer follows, little benefit is produced by the dung, which is dried up, and most of the juices evaporated. A better method is to make a compost with earth and dung, and, where it can be easily obtained, with chalk, or the old mortar of buildings pulled down. The best earth is that which contains most vegetable matter; and as many of these meadows are on a stiff clay soil, which requires to be kept dry by open drains and water furrows, the soil dug out of these and carted to a corner of the meadow makes an excellent foundation for the compost. It is sometimes useful to plough furrows at intervals to take off the superfluous surface-water in winter; the earth thus raised by the plough is excellent to mix in the compost; having been turned over with dung, sweepings of streets, or any other manure, so as to form a uniform mass, it is spread over the land in winter; and in spring a bush-harrow is drawn over the meadow, and it is rolled with a heavy roller. All this compost is soon washed into the ground, and invigorates the roots of the grass. It is better to put on a slight coating of this compost every year than to give a greater portion of manure every three or four years, as is the practice of some farmers. When grass land is let to a tenant, it requires some attention, and particular conditions in the lease, to prevent the meadows being deteriorated by continual mowing without sufficient manuring, which might be the case near the expiration of the lease. It is very common to insist, by a clause, on a cart-load of stable dung being bought for every load of hay which is made and not consumed on the premises. Sometimes the tenant is bound to feed the land in alternate years; but if horses or heavy cattle should be taken in, especially in spring and autumn, they may do more harm by their treading, when the ground is soft, than would have been done by taking off a crop of hay. When the proprietor of meadows resides near them, he often finds it most profitable to keep them in hand, and sell the crop when it is fit to be mown. In that case he must be careful to manure them sufficiently, or his profits will soon diminish rapidly. The grazing of cattle has generally been a more profitable occupation than simply tilling the land. The capital required is considerable, but the current expenses are not great. The grazier is not subject to such total failures as the farmer of arable land is in his crops. With a little experience and prudence, he can always reckon on a certain return. An acre of good grazing land, worth 40s. rent, is supposed to produce 200 lb. of meat in the year. If this is worth 6*d.* a pound, the gross produce is 5*l.* per acre. The expenses will not exceed 10*s.* per acre, so that here is a net profit of 2*l.* 10s. per acre with little or no risk; few arable farms will average this net profit. By uniting the raising of corn and the grazing of cattle and sheep, the greatest profit is probably obtained, and this is the great argument in favour of the convertible system of husbandry.

The value of pasture land, and of some of the sown grasses, especially the Italian rye-grass, under irrigation and under the application of sewage-manure, will be considered hereafter. [Irrigation.]

GRAVE. [Accent.]

GRAVER. [Engraving.]

GRAVITATION. Section I.—*On the Rules for calculating Attraction, or the Law of Gravitation.*

(1.) The principle upon which the motions of the earth, moon, and planets are calculated is this: Every particle of matter *attracts* every other particle. That is, if there were a single body alone, and at rest, then, if a second body were brought near it, the first body would immediately begin to move towards the second body. Just in the same manner, if a needle is at rest on a table, and if a magnet is brought near it, the needle immediately begins to move towards the magnet, and we say that the magnet attracts the needle. But magnetic attraction belongs only to certain bodies: whereas the attraction of which we speak here belongs to all bodies of every kind: metals, earths, fluids, and even the air and gases are equally subject to its influence.

(2.) The most remarkable experiments which prove that bodies attract each other are a set of experiments made at the end of the last century by Mr. Cavendish. Small leaden balls were supported on the ends of a rod which was suspended at the middle by a slender wire; and when large leaden balls were brought near to them, it was found that the wire was immediately twisted by the motion of the balls. But the results of this experiment are striking, principally because they are unusual; the ordinary force of gravity serves quite as well to prove the existence of some such power. For when we consider that the earth is round, and that, on all parts of it, bodies, as soon as they are at liberty, fall in directions perpendicular to its surface, (and therefore fall in opposite directions at the places which are diametrically opposite,) we are compelled to allow that there is a force such as we call attraction, either directed to the centre of the earth, or produced by a great number of small forces, directed to all the different particles composing the earth. The peculiar value of Cavendish's experiment consists in showing that there is a small force directed to every different particle of the earth.

(3.) But it is necessary to state distinctly the rules by which this attraction is regulated, and by which it may be calculated; or (as it is technically called) *the law of gravitation*. Before we can do this, we must determine which of the effects of attraction we choose to take as its measure. For there are two distinct effects: one is the *pressure* which it produces upon any obstacle that keeps the body at rest; the other is the *space through which it draws the body in a certain time*, if the obstacle is removed and the body set at liberty. Thus, to take the ordinary force of gravity as an instance: we might measure it by the pressure which is produced on the hand by a lump of lead held in the hand; or we might measure it by the number of inches through which the lump of lead would fall in a second of time after the hand is opened (as the pressure and fall are both occasioned by gravity). But there is this difference between the two measures: if we adopted the first, since a great lump of lead weighs more than a small one, we should find a different measure by the use of every different piece of lead; whereas, if we adopt the second, since it is well established by careful and accurate experiments that large and small lumps of lead, stones, and even feathers, fall through the same number of inches in a second of time, (when the resistance of the air, &c., is removed,) we shall get the same measure for gravity, whatever body we suppose subject to its influence. The consistence and simplicity of the measure thus obtained incline us to adopt it in every other case; and thus we shall say, *Attraction is measured by the space through which it draws a body in one second of time after the body is set at liberty.*

(4.) Whenever we speak, therefore, of calculating attraction, it must be understood to mean calculating the number of inches, or feet, through which the attraction draws a body in one second of time.

(5.) Now the first rule is this: "The attraction of one body upon another body does not depend on the mass of the body which is attracted, but is the same whatever be the mass of the body so attracted, if the distances are the same."

(6.) Thus Jupiter attracts the sun, and Jupiter attracts the earth also; but though the sun's mass is three hundred thousand times as great as the earth's, yet the attraction of Jupiter on the sun is exactly equal to his attraction on the earth, when the sun and the earth are equally distant from Jupiter. In other words, (the attraction being measured in conformity with the definition above,) when the sun and the earth are at equal distances from Jupiter, the attraction of Jupiter draws the sun through as many inches, or parts of an inch, in on second of time as it draws the earth in the same time.

(7.) The second rule is this: "Attraction is proportional to the mass of the body which attracts, if the distances of different attracting bodies be the same."

(8.) Thus, suppose that the sun and Jupiter are at equal distances from Saturn; the sun is about a thousand times as big as Jupiter; then whatever be the number of inches through which Jupiter draws Saturn in one second of time, the sun draws Saturn in the same time through a thousand times that number of inches.

(9.) The third rule is this: "If the same attracting body act upon several bodies at different distances, the attractions are inversely proportional to the square of the distances from the attracting body.

(10.) Thus the earth attracts the sun, and the earth also attracts the moon; but the sun is four hundred times as far off as the moon, and therefore, the earth's attraction on the sun is only $\frac{1}{160000}$th part of its attraction on the moon; or, as the earth's attraction draws the moon through about $\frac{1}{20}$th of an inch in one second of time, the earth's attraction draws the sun through $\frac{1}{3200000}$th of an inch in one second of time. In like manner, supposing Saturn ten times as far from the sun as the earth is, the sun's attraction upon Saturn is only one hundredth part of his attraction on the earth.

(11.) The same rule holds in comparing the attractions which one body exerts upon another, when, from moving in different paths, and with different degrees of swiftness, their distance is altered. Thus Mars, in the spring of 1833, was twice as far from the earth as in the autumn of 1832; therefore, in the spring of 1833, the earth's attraction on Mars was only one-fourth of its attraction on Mars in the autumn of 1832. Jupiter is three times as near to Saturn, when they are on the same side of the sun as when they are on opposite sides; therefore, Jupiter's attraction on Saturn, and Saturn's attraction on Jupiter, are nine times greater when they are on the same side of the sun than when they are on opposite sides.

(12.) The reader may ask, How is all this known to be true? The best answer is, perhaps, the following: We find that the force which the earth exerts upon the moon bears the same proportion to gravity on the earth's surface which it ought to bear in conformity with the rule just given. For the motions of the planets, calculations are made, which are founded upon these laws, and which will enable us to predict their places with considerable accuracy, if the laws are true, but which would be much in error if the laws were false. The accuracy of astronomical observations is carried to a degree that can scarcely be imagined; and by means of these we can every day compare the observed place of a planet with the place which was calculated beforehand, according to the law of gravitation. It is found that they agree so nearly as to leave no doubt of the truth of the law. The motion of Jupiter, for instance, is so perfectly calculated, that astronomers have computed ten years beforehand the time at which it will pass the meridian of different places, and we find the predicted time correct within half a second of time.

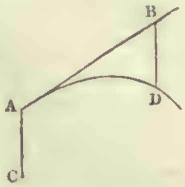
SECTION II.—*On the Effect of Attraction upon a Body which is in motion, and on the Orbital Revolutions of Planets and Satellites.*

(13.) We have spoken of the simplest effects of attraction, namely, the production of pressure, if the matter on which the attraction acts is supported (as when a stone is held in the hand), and the production of motion if the matter is set at liberty (as when a stone is dropped from the hand). And it will easily be understood, that when a body is projected, or thrown, in the same direction in which the force draws it (as when a stone is thrown downwards), it will move with a greater velocity than either of these causes separately would have given it; and if thrown in the direction opposite to that in which the force draws it (as when a stone is thrown upwards), its motion will become slower and slower, and will, at last, be turned into a motion in the opposite direction. We have yet to consider a case much more important for astronomy than either of these: Suppose that a body is projected in a direction *transverse to*, or *crossing*, the direction in which the force draws it, how will it move?

(14.) The simplest instance of this motion that we can imagine is the motion of a stone when it is thrown from the hand in a horizontal direction, or in a direction nearly horizontal. We all know that the stone soon falls to the ground; and if we observe its motion with the least attention, we see that it does not move in a straight line. It begins to move in the direction in which it is thrown; but this direction is speedily changed; it continues to change gradually and constantly, and the stone strikes the ground, moving at that time in a direction much inclined to the original direction. The most powerful effort that we can make, even when we use artificial means (as in producing the motion of a bomb or a cannon-ball), is not sufficient to prevent the body from falling at last. This experiment therefore will not enable us immediately to judge what will become of a body (as a planet) which is put in motion at a great distance from another body, which attracts it (as the sun); but it will assist us much in judging generally what is the nature of motion when a body is projected in a direction transverse to the direction in which the force acts on it.

(15.) It appears then that the general nature of the motion is this: the body describes a curved path, of which the first part has the same direction as the line in which it is projected. The circumstances of the motion of the stone may be calculated with the utmost accuracy from the following rule, called the second law of motion (the accuracy of which has been established by many simple experiments, and many inferences from complicated motion). If A, *fig.* 1, is the point from which the stone was thrown, and A B the direction in which it was thrown; and if we wish to know where the stone will be at the end of any particular time (suppose, for instance, three seconds), and if the velocity with which it is thrown would, in three seconds, have carried it to B, supposing gravity not to have acted on it; and if gravity would have made it fall from A to C, supposing it to have been merely dropped from the hand; then, at the end of three seconds, the stone really will be at the point D, which is determined by drawing B D parallel and equal to A C; and it will have reached it by a curved path A D, of which different points can be determined in the same way for different instants of time.

Fig. 1.

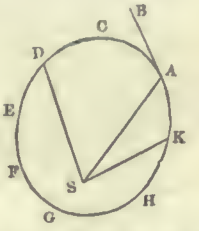


(16.) The calculation of the stone's course is easy, because, during the whole motion of the stone, gravity is acting upon it with the same force and in the same direction. The circumstances of the motion of a body attracted by a planet, or by the sun (where the force, as we have before mentioned, is inversely proportional to the square of the distance, and therefore varies as the distance alters, and is not the same, either in its amount or in its direction, at the point D as it is at the point C), cannot be computed by the same simple method. But the same method will apply, provided we restrict the intervals for which we make the calculations to times so short, that the alterations in the amount of the force, and in its direction, during each of those times, will be very small. Thus, in the motion of the earth, as affected by the attraction of the sun, if we used the process that we have described, to find where the earth will be at the end of a month from the present time, the place that we should find would be very far wrong; if we calculated for the end of a week, since the direction of the force (always directed to the sun) and its magnitude (always proportional inversely to the square of the distance from the sun) would have been less altered, the circumstances would have been more similar to those of the motion of the stone, and the error in the place that we should find would be much less than before; if we calculated by this rule for the end of a day, the error would be so small as to be perceptible only in the nicest observations; and if we calculated for the end of a minute, the error would be perfectly insensible.

(17.) Now a method of calculation has been invented, which amounts to the same as making this computation for every successive small portion of time, with the correct value of the attractive force and the correct direction of force at every particular portion of time, and finding thus the place where the body will be at the end of any time that we may please to fix on, without the smallest error. The rules to which this leads are simple: but the demonstration of the rules requires the artifices of advanced science. We cannot here attempt to give any steps of this demonstration; but our plan requires us to give the results.

(18.) It is demonstrated that if a body (a planet for instance) is by some force projected from A, *fig.* 2, in the direction A B, and if the attraction of the sun, situated at S, begins immediately to act on it, and continues to act on it according to the law that we have mentioned (that is, being inversely proportional to the square of its distance from S, and always directed to S); and if no other force whatever but this attraction acts upon the body; then the body will move in one of the following curves—a circle, an ellipse, a parabola, or a hyperbola.

Fig. 2.



In every case the curve will, at the point A, have the same direction as the line A B: or (to use the language of mathematicians), A B will be a tangent to the curve at A.

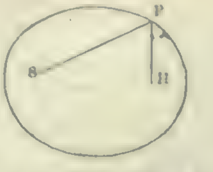
The curve cannot be a circle unless the line A B is perpendicular to S A, and, moreover, unless the velocity with which the planet is projected is neither greater nor less than one particular velocity determined by the length of S A and the mass of the body S. If it differs little from this particular velocity (either greater or less), the body will move in an ellipse; but if it is much greater, the body will move in a parabola or a hyperbola.

If A B is oblique to S A, and the velocity of projection is small, the body will move in an ellipse; but if the velocity is great, it may move in a parabola or hyperbola, but not in a circle.

If the body describe a circle, the sun is the centre of the circle.

If the body describe an ellipse, the sun is not the centre of the ellipse, but one focus. (The method of describing an ellipse is to fix two pins in a board, as at S and H, *fig.* 3; to fasten a thread S P H to them, and to keep this thread stretched by the point of a pencil, as at P; the pencil will trace out an ellipse, and the places of the pins S and H will be the two focuses.)

Fig. 3.



If the body describe a parabola or hyperbola, the sun is in the focus.

(19.) The planets describe ellipses which are very little flattened, and differ very little from circles. Three or four comets describe very long ellipses; and nearly all the others that have been observed are found to move in curves which cannot be distinguished from parabolas. There is reason to think that two or three comets which have been observed move in hyperbolas. But as we do not propose, in this treatise, to enter into a discussion on the motions of comets, we shall confine ourselves to the consideration of motion in an ellipse.

(20.) Everything that has been said respecting the motion of a planet, or body of any kind, round the sun, in consequence of the sun's attraction according to the law of gravitation, applies equally well to the motion of a satellite about a planet, since the planet attracts with a force following the same law (though smaller) as the attraction of the sun. Thus the moon describes an ellipse round the earth, the earth being the focus of the ellipse; Jupiter's satellites describe each an ellipse about Jupiter, and Jupiter is in one focus of each of those ellipses; the same is true of the satellites of Saturn and Uranus.

(21.) In stating the suppositions on which the calculations of orbits are made, we have spoken of a force of attraction, and a force by which a planet is projected. But the reader must observe that the nature of these forces is wholly different. The force of attraction is one which acts constantly and steadily without a moment's intermission (as we know that gravity to the earth is always acting): the force by which the body is projected is one which we suppose to be necessary at some past time to account for the planet's motion, but which acts no more. The planets *are in motion*, and it is of no consequence to our inquiry how they received this motion, but it is convenient, for the purposes of calculation, to suppose that, at some time, they received an impulse of the same kind as that which a stone receives when thrown from the hand; and this is the whole meaning of the term "projectile force."

(22.) From the same considerations it will appear that, if in any future investigations we should wish to ascertain what is the orbit described by a planet after it leaves a certain point where the velocity and direction of its motion are known, we may suppose the planet to be projected from that point with that velocity and in that direction. For it is unimportant by what means the planet acquires its velocity, provided it has such a velocity there.

(23.) We shall now allude to one of the points which, upon a cursory view, has always appeared one of the greatest difficulties in the theory of elliptic revolution; but which, when duly considered, will be found to be one of the most simple and natural consequences of the law of gravitation.

(24.) The force of attraction, we have said, is inversely proportional to the square of the distance, and is therefore greatest when the distance is least. It would seem then, at first sight, that when a planet has approached most nearly to the sun, as the sun's attraction is then greater than at any other time, the planet must inevitably fall to the sun. But we assert that the planet begins then to recede from the sun, and that it attains at length as great a distance as before, and goes on continually retracing the same orbit. How is this receding from the sun to be accounted for?

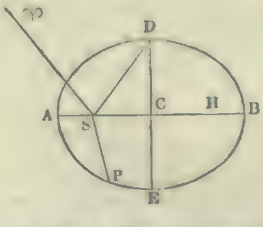
(25.) The explanation depends on the increase of velocity as the planet approaches to the point where its distance from the sun is least, and on the considerations by which we determine the form of the curve which a certain attracting force will cause a planet to describe. In explaining the motion of a stone thrown from the hand, to which the motion of a planet for a very small time is exactly similar, we have seen that the deflection of the stone from the straight line in which it began to move is exactly equal to the space through which gravity could have made it fall in the same time from rest, whatever were the velocity with which it was thrown. Consequently, when the stone is thrown with very great velocity, it will have gone a great distance before it is much deflected from the straight line, and therefore its path will be very little curved; a fact familiar to the experience of every one. The same thing holds with regard to the motion of a planet; and thus the curvature of any part of the orbit which a planet describes will not depend simply upon the force of the sun's attraction, but will also depend on the velocity with which the planet is moving. The greater is the velocity of the planet at any point of its orbit, the less will the orbit be curved at that part. Now if we refer to *fig.* 2, we shall see that, supposing the planet to have passed the point C with so small a velocity that the attraction of the sun bends its path very much, and causes it immediately to begin to approach towards the sun: the sun's attraction will necessarily increase its velocity as it moves through D, E, and F. For the sun's attractive force on the planet, when the planet is at D, is acting in the direction D S, and it is plain that (on account of the small inclination of D E to D S) the force pulling in the direction D S helps the planet along in its path D E, and thereby increases its velocity. Just as when a ball rolls down a sloping bank, the force of gravity (whose direction is not much inclined to the bank) helps the ball down the bank, and thereby increases its velocity. In this manner, the velocity of the planet will be continually increasing as the planet passes through D, E, and F; and though the sun's attractive force (on account of the planet's nearness) is very much increased, and tends, therefore, to make the orbit more curved, yet the velocity is so much increased that, on that account, the orbit is not more curved than before. Upon making the calculation more accurately, it is found that the planet, after leaving C, approaches to the sun more and more rapidly for about a quarter of its time of revolution; then for about a quarter of its time of revolution the velocity of its approach is constantly diminishing: and at half the periodic time after leaving C, the planet is no longer approaching to the sun; and its velocity is so great, and the curvature of the orbit in consequence so small (being, in fact, exactly the same as at C), that it begins to recede. After this it recedes from the sun by exactly the same degrees by which it before approached it.

(26.) The same sort of reasoning will show why, when the planet reaches its greatest distance, where the sun's attraction is least, it does not altogether fly off. As the planet passes along H, K, A, the sun's attraction (which is always directed to the sun) retards the planet in its orbit, just as the force of gravity retards a ball which is bowled up a hill; and when it has reached C, its velocity is extremely small; and, therefore, though the sun's attraction at C is small, yet the deflection which it produces in the planet's motion is, (on account of the planet's slowness there) sufficient to make its path very much curved, and the planet approaches the sun, and goes over the same orbit as before.

(27.) The following terms will occur perpetually in the rest of this article, and it is therefore desirable to explain them now.

Let S and H, *fig.* 4, be the focuses of the ellipse A E B D; draw the line A B through S and H; take C the middle point between S and H, and draw D C E perpendicular to A C B. Let S be that focus which is the place of the sun, (if we are speaking of a planet's orbit,) or the place of the planet, (if we are speaking of a satellite's orbit).

Fig. 4.



Then A B is called the *major axis* of the ellipse.

C is the *centre*.

A C or C B is the *semi-major axis*. This is equal in length to S D; it is sometimes called the *mean distance*, because it is half-way between A S (which is the planet's smallest distance from S) and B S (which is the planet's greatest distance from S).

D E is the *minor axis*, and D C or C E the *semi-minor axis*.

A is called the *perihelion* (if we are speaking of a planet's orbit); the *perigee* (if we are speaking of the orbit described by our moon about the earth); the *perijove* (if we are speaking of the orbit described by one of Jupiter's satellites round Jupiter); or the *perisaturnium* (if we are speaking of the orbit described by one of Saturn's satellites about Saturn.)

B, in the orbit of a planet, is called the *aphelion*; in the moon's orbit it is called the *apogee*; in the orbit of one of Jupiter's satellites, we shall call it the *apojove*.

A and B are both called *apses*; and the line A B, or the major axis, is sometimes called the *line of apses*.

S C is sometimes called the *linear excentricity*: but it is more usual to speak only of the proportion which S C bears to A C, and this proportion, expressed by a number, is called the *excentricity*. Thus, if S C were one-third of A C, we should say, that the excentricity of the orbit was $\frac{1}{3}$, or 0·3333.

If S ♈ is drawn towards a certain point in the heavens, called the *first point of Aries*, then the angle ♈ S A is called the *longitude of perihelion* (or of perigee, or of perijove, &c.).

If P is the place of the planet in its orbit at any particular time, then the angle ♈ S P is its *longitude* at that time, and the angle A S P is its *true anomaly*. (The longitude of the planet is, therefore, equal to the sum of the longitude of the perihelion, and the true anomaly of the planet.) The line S P is called the *radius vector*.

In all our diagrams it is to be understood, that the planet, or satellite, moves through its orbit in the direction opposite to the motion of the hands of a watch. This is the direction in which all the planets and satellites would appear to move, if viewed from any place on the north side of the planes of their orbits.

The time in which the planet moves from any one point of the orbit through the whole orbit, till it comes to the same point again, is called the planet's *periodic time*.

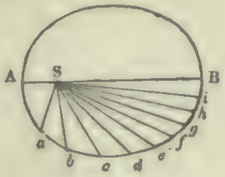
(28.) If we know the mass of the central body, and if we suppose the revolving body to be projected at a certain place in a known direction with a given velocity, the length of the axis major, the excentricity, the position of the line of apses, and the periodic time, may all be calculated. We cannot point out the methods and formulæ used for these, but we may mention one very remarkable result. The length of the axis major depends only upon the velocity of projection, and upon the place of projection, and not at all upon the direction of projection.

(29.) We shall proceed to notice the principle on which the motion of a planet, or satellite, in its orbit, is calculated.

It is plain that this is not a very easy business. We have already explained, that the velocity of the planet in its orbit is not uniform (being greatest when the planet's distance from the sun is least, or when the planet is at perihelion); and it is obvious, that the longitude of the planet increases very irregularly; since, when the planet is near to the sun, its actual motion is very rapid, and, therefore the increase of longitude is extremely rapid; and when the planet is far from the sun, its actual motion is slow, and, therefore, the increase of longitude is extremely slow. The rule which is demonstrated by theory, and which is found to apply precisely in observation, is this:—The areas described by the radius vector are equal in equal times. This is true, whether the force be inversely as the square of the distance from the central body, or be in any other proportion, provided that it is directed to the central body.

(30.) Thus, if in one day a planet, or a satellite, moves from A to *a*, *fig.* 5; in the next day it will move from *a* to *b*, making the area *a* S *b* equal to A S *a*; in the third day it will move from *b* to *c*, making the area *b* S *c* equal to A S *a* or *a* S *b*, and so on.

Fig. 5.



(31.) Upon this principle mathematicians have invented methods of calculating the place of a planet or satellite, at any time for which it may be required. These methods are too troublesome for us to explain here; but we may point out the meaning of two terms which are frequently used in these computations. Suppose, for instance, as in the figure, that the planet, or satellite, occupies ten days in describing the half of its orbit, A *a b c d e f g h i* B, or twenty days in describing the whole orbit; and suppose that we wished to find its place at the end of three days after leaving the perihelion. If the orbit were a circle, the planet would in three days have moved through an angle of 54 degrees. If the excentricity of the orbit were small (that is, if the orbit did not differ much from a circle), the angle through which the planet would have moved would not differ much from 54 degrees. The excentricities of all the orbits of the planets are small; and it is convenient, therefore, to begin with the angle 54° as one which is not very erroneous, but which will require some correction. This angle (as 54°), which is proportional to the time, is called the *mean anomaly*; and the correction which it requires, in order to produce the true anomaly, is called the *equation of the centre*. If we examine the nature of the motion, while the planet moves from A to B, it will be readily seen, that during the whole of that time, the angle really described by the planet is *greater* than the angle which is proportional to the time, or the equation of the centre is to be *added* to the mean anomaly, in order to produce the true anomaly; but while the planet moves in the other half of the orbit, from B to A, the angle really described by the planet is *less* than the angle which is proportional to the time, or the equation of the centre is to be *subtracted from* the mean anomaly, in order to produce the true anomaly.

(32.) The sum of the mean anomaly and the longitude of perihelion is called the *mean longitude* of the planet. It is evident, that if we add the equation of the centre to the mean longitude, while the planet is moving from A to B, or subtract it from the mean longitude, while the planet is moving from A to B, as in (31), we shall form the true longitude.

(33.) The reader will see, that when the planet's true anomaly is calculated, the length of the radius vector can be computed from a knowledge of the properties of the ellipse. Thus the place of the planet, for any time, is perfectly known. This problem has acquired considerable celebrity under the name of Kepler's problem.

(34.) There remains only one point to be explained regarding the undisturbed motion of planets and satellites; namely, the relation between a planet's periodic time and the dimensions of the orbit in which it moves.

Now, on the law of gravitation it has been demonstrated from theory, and it is fully confirmed by observation, that the periodic time does not depend on the excentricity, or on the perihelion distance, or on the aphelion distance, or on any element except the *mean distance* or semi-major axis. So that if two planets moved round the sun, one in a circle, or in an orbit nearly circular, and the other in a very flat ellipse; provided their mean distances were equal, their periodic times would be equal. It is demonstrated also, that for planets at different distances, the relation between the periodic times and the mean distances is the following: The squares of the number of days (or hours, or minutes, &c.) in the periodic times have the same proportion as the cubes of the numbers of miles (or feet, &c.) in the mean distances.

(35.) Thus the periodic time of Jupiter round the sun is 4332·7 days, and that of Saturn is 10759·2 days; the squares of these numbers are 18772289 and 115760385. The mean distance of Jupiter from the sun is about 487491000 miles, and that of Saturn is about 893955000 miles; the cubes of these numbers are 1158496 (20 ciphers), and 7144088 (20 ciphers). On trial it will be found, that 18772289 and 115760385 are in almost exactly the same proportion as 1158496 and 7144088.

(36.) In like manner, the periodic times of Jupiter's third and fourth satellites round Jupiter are 7·15455 and 16·68877 days; the squares of these numbers are 51·1876 and 278·515. Their mean distances from Jupiter are 670080 and 1178560 miles; the cubes of these numbers are 300866 (12 ciphers), and 1667029 (12 ciphers), and the proportion of 51·1876 to 278·515 is almost exactly the same as the proportion of 300866 to 1637029.

(37.) It must however be observed that this rule applies in comparing the periodic times and mean distances, *only* of bodies which revolve round the *same* central body. Thus the rule applies in comparing the periodic times and mean distances of Jupiter and Saturn, because they both revolve round the sun; it applies in comparing the periodic times and mean distances of Jupiter's third and fourth satellites, because they both revolve round Jupiter; but it would not apply in comparing the periodic time and mean distance of Saturn revolving round the sun with that of Jupiter's third satellite revolving round Jupiter.

(38.) In comparing the orbits described by different planets, or satellites, round different centres of force, theory gives us the following law:—The cubes of the mean distances are in the same proportion as the products of the mass by the square of the periodic time. Thus, for instance, the mean distance of Jupiter's fourth satellite from Jupiter is 1178560 miles; its periodic time round Jupiter is 16·68877 days; the mean distance of the earth from the sun is 93726900 miles; its periodic time round the sun is 365·2564 days; also the mass of Jupiter is $\frac{1}{1050}$th the sun's mass. The cubes of the mean distances are respectively 1637029 (12 ciphers), and 823365 (18 ciphers); the products of the squares of the times by the masses are respectively 0·265252 and 133412; and these numbers are in the same proportion as 1637029 (12 ciphers), and 823365 (18 ciphers).

(39.) The three rules—that planets move in ellipses, that the radius vector in each orbit passes over areas proportional to the times, and that the squares of the periodic times are proportional to the cubes of the mean distances,—are commonly called Kepler's laws. They were discovered by Kepler from observation, before the theory of gravitation was invented; they were first explained from the theory by Newton, about the year 1680.

(40.) The last of these is not strictly true, unless we suppose that the central body is absolutely immoveable. This however is evidently inconsistent with the principles which we have laid down in Section I. In considering the motion, for instance, of Jupiter round the sun, it is necessary to consider that, while the sun attracts Jupiter, Jupiter is also attracting the sun. But the planets are so small in comparison with the sun (the largest of them, Jupiter, having less than one-thousandth part of the matter contained in the sun), that in common illustrations there is no need to take this consideration into account. For nice astronomical purposes it is taken into account in the following manner:—The motion which the attraction of Jupiter produces in the sun is less than the motion which the attraction of the sun produces in Jupiter, in the same proportion in which Jupiter is smaller than the sun. If the sun and Jupiter were allowed to approach one another, their rate of approach would be the *sum* of the motions of the sun and Jupiter, and would therefore be greater than their rate of approach, if the sun were not moveable, in the same proportion in which the sum of the masses of the sun and Jupiter is greater than the sun's mass; that is, the rate of approach of the sun and Jupiter, both being free, is the same as the rate of approach would be if the sun were fixed, provided the sun's mass were increased by adding Jupiter's mass to it. Consequently, in comparing the orbits described by different planets round the sun, we must use the rule just laid down, supposing the central force to be the attraction of a mass equal to the sum of the sun and the planet; and thus we get a proportion which is rigorously true: for different planets, or even for different bodies revolving round different centres of force, the cubes of the mean distances are in the same proportion as the products of the square of the periodic time by the sum of the masses of the attracting and attracted body.

SECTION III.—*General Notions of Perturbation; and Perturbation of the Elements of Orbits.*

(41.) We have spoken of the motion of two bodies (as the sun and a planet) as if no other attracting body existed. But, as we have stated in Section I., every planet and every satellite attracts the sun and every other planet and satellite. It is plain now that, as each planet is attracted very differently at different times by the other planets whose position is perpetually varying, the motion is no longer the same as if it was only attracted by the sun. The planets therefore do not move exactly in ellipses; the radius vector of each planet does not pass over areas exactly proportional to the times; and the proportion of the cube of the mean distance to the product of the square of the periodic time by the sum of the masses of the sun and the planet, is not strictly the same for all. Still the disturbing forces of the other planets are so small in comparison with the attraction of the sun, that these laws are very nearly true; and (except for our moon and the other satellites) it is only by accurate observation, continued for some years, that the effects of perturbation can be made sensible.

(42.) The investigation of the effects of the disturbing forces will consist of two parts: the examination into the effects of disturbing forces generally upon the motion of a planet, and the examination into the kind of disturbing force which the attraction of another planet produces. We shall commence with the former; we shall suppose that a planet is revolving round the sun, the sun being fixed (a supposition made only for present convenience), and that some force acts on the planet without acting on the sun (a restriction introduced only for convenience, and which we shall hereafter get rid of).

(43.) The principle upon which we shall explain the effect of this force is that known to mathematicians by the name of *variation of elements*. The planet, as we have said, describes some curve which is not strictly an ellipse, or indeed, any regularly formed curve. It will not even describe the same curve in successive revolutions. Yet its motion may be represented by supposing it to have moved in an ellipse, provided we suppose the elements of the ellipse to have been perpetually altering. It is plain that by this contrivance any motion whatever may be represented. By altering the major axis, the excentricity, and the longitude of perihelion, we may in many different ways make an ellipse that will pass through any place of the planet; and by altering them in some particular proportions, we may, in several ways, make an ellipse in which the direction of motion at the place of the planet shall be the same as the direction of the planet's motion. But there is only one ellipse which will pass exactly through a place of the planet, in which the direction of the motion at that place shall be exactly the same as the direction of the planet's motion, and in which the velocity (in order that a body may revolve in that ellipse round the sun) will be the same as the planet's real velocity. The dimensions and position of this ellipse may be conceived as follows; if at any instant we suppose the disturbing force to cease, and conceive the planet to be as it were projected with the velocity which it happens to have at that instant, the attraction of the sun or central body will cause it to describe the ellipse of which we are speaking. We shall in future mention this by the name of the *instantaneous ellipse*.

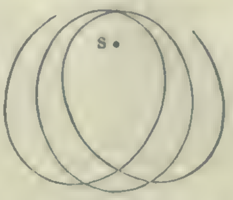
(44.) If the disturbing force ceases, the planet continues to revolve in the same ellipse, and the permanent ellipse coincides with the instantaneous ellipse corresponding to the instant when the disturbing force ceases.

(45.) If the disturbing force continues to act, the dimensions of the instantaneous ellipse are continually changing: but in the course of a single revolution (even for our moon), the dimensions alter so little, that the motion in the instantaneous ellipse corresponding to any instant during that revolution will very nearly agree with the real motion during that revolution.

We shall now consider the effects of particular forces in altering the elements.

(46.) (I.) Suppose that the disturbing force is always directed to the central body. The effect of this would be nearly the same as if the attraction, or the mass of the central body, was increased. The result of this on the dimensions of the orbit will be different according to the part of the orbit where it begins to act, and may be gathered from the cases to be mentioned separately hereafter (we do not insist on it at present, as there is no instance in the planetary system of such sudden commencement of force). But at all events the relation between the mean distance and the periodic time will not be the same as before; the time will be less for the same mean distance, or the mean distance greater for the same periodic time than if the disturbing force did not act (38). If the disturbing force is always directed from the central body, the effect will be exactly opposite. If the disturbing force does not alter, except with the planet's distance, the planet will at every successive revolution describe an orbit of the same size. For, as we have stated (29), the radius vector will in equal times pass over equal areas; and mathematicians have proved that, if the variation of force depends only on the distance, the velocity of the planet will depend only on the distance; and the consideration which determines the greater or least distance of the planet is, that the planet, moving with the velocity which is proper to the distance, cannot describe the proper area in a short time, unless it move in the direction perpendicular to the radius vector. This consideration will evidently give the same values for the greatest and least distances at every revolution. It may happen that all the greatest distances will not be at the same place; the body may describe such an orbit as that in *fig.* 6.

Fig. 6.



(47.) (II.) If, however, the disturbing force directed to the central body increases gradually and constantly during many revolutions, there is no difficulty in seeing that the planet will at every revolution be drawn nearer to the central body, and thus it will move, at every succeeding revolution, in a smaller orbit than at the preceding one; and will consequently perform its revolution in a shorter time. If the disturbing force directed to the central body diminishes, the orbit will become larger, and the periodic time longer. In the same manner, if the disturbing force is directed from the central body, a gradual increase of the disturbing force will increase the dimensions of the orbit and the periodic time, and a gradual diminution of the disturbing force will diminish the dimensions of the orbit and the periodic time.

(48.) (III.) Suppose that the disturbing force acts always in the direction in which the planet is moving. The reader might imagine at first sight that this would shorten the time of revolution. The effect, however, is exactly opposite; for in *fig.* 2, if the planet be projected from A, the reason that the sun's attraction is able to pull the planet in at C and make it approach to itself is, that the velocity of the planet is so small as to allow the force to curve the orbit much. If the velocity were greater, the orbit—as we have said in (25)—would be *less curved* in every part, and would therefore pass on the *outside* of the orbit A C D E F. The effect then of a force in the direction of the planet's motion, which increases the planet's velocity, is to increase the size of its orbit; and the bigger the orbit is, the longer is the time of revolution. If the force acts continually, the time of revolution lengthens continually. If the disturbing force acts in the direction opposite to that in which the planet is moving, the effect is to make the orbit smaller, and to make the time of revolution shorter. The retardation produced by motion through extremely thin air is of this kind: it is found that a comet (known by the name of Encke's comet) which moves in an ellipse, whose length is not much greater than the diameter of Mars' orbit, performs every new revolution in a shorter time than the preceding one; and we infer from this circumstance that it experiences some resistance in its motion.

(49.) (IV.) There is one consideration of great importance in the estimation of the effects mentioned in (II.) and (III.). The alteration of the dimensions of the orbit produces an alteration in the periodic time, and this alters the planet's *mean motion*, or the number of degrees by which the mean longitude is increased in a given time (suppose one year). The effects of these alterations are added together at every successive revolution, and thus may produce an alteration in the planet's mean longitude (which differs from the true longitude only by the equation of the centre) that is vastly more conspicuous than the alteration in the dimensions of the orbit. Suppose, for instance, that a disturbing force acted on a planet (either a constant force in the direction of its motion, or a variable force in the direction of the radius vector), such as to increase the mean distance by $\frac{1}{10000}$th part in 100 revolutions of the planet. This alteration of the planet's distance from the sun could hardly be discovered by the nicest observations. But as the mean distance has been altered in the proportion of 10000 : 10001, the periodic time will have been altered in the proportion of 10000 : 10001½ nearly, or the mean motion will have been altered in the proportion of 10001½ to 10000, or 1 : 0·99985 nearly. If this alteration has gone on uniformly, we may suppose the whole motion in the 100 revolutions to have been nearly the same as if the planet had moved with a mean motion, whose value is half way between the values of the first and the last, or 0·999925 × the original mean motion. Therefore, at the time when we should expect the planet to have made 100 revolutions, it will only have made 99·9925 revolutions, or will be *behind* the place where we expected to see it by 0·0075 revolution, or nearly three degrees; a quantity which could not fail to be noticed by the coarsest observer. To use a borrowed illustration, the alteration of the mean distance in an orbit produces the same kind of effect as the alteration of the length of a clock pendulum which, though so small as to be insensible to the eye, will in a few days produce a very great effect on the time shown by the clock.

(50.) (V.) Now, suppose the orbit of the planet or satellite to be an ellipse; and suppose a disturbing force directed to the central body to act upon the planet, &c., only when it is near its perihelion or perigee, &c. In *fig.* 7, let A B be the curve in which the planet is moving, and let the dotted line B C D A represent the orbit in which it would have moved if no disturbing force had acted, C being the place of perihelion. At B let the disturbing force, directed towards S, begin to act, and let it act for a little while, and then cease. The planet is at that place approaching toward the sun, and the direction of its motion makes an acute angle with S B. It is evident that the disturbing force, which draws the planet more rapidly towards the sun without otherwise affecting its motion, will cause it to move in a direction that makes a more acute angle with S B. The part of the new path, therefore, which is nearest to the sun (that is, the new perihelion) will be farther from B than the perihelion C of the orbit in which the planet would have moved. The reader's conception of this will be facilitated by supposing the orbit, instead of a curve, to be a straight line, as B C in *fig.* 7*, and the place of perihelion to be determined by letting fall a perpendicular S C from the sun upon the line, when it will be seen that if the disturbing force, acting towards S for a short time at B, changes the path of the planet from the direction B C to B *c*, the distance of the foot of the perpendicular S *c* from B is greater than that of S C. With a curved orbit the result is just the same. In other words, the planet, instead of describing B C *fig.* 7, will, in consequence of the action of the disturbing force, describe B *c*; and the place of perihelion, instead of C, will be *c*, a point more distant from B than C is. Now, if the disturbing force should not act again, the planet would move in an ellipse *c d b*, and the line of apses, instead of C S D, would be *c* S *d*. The line of apses has, therefore, twisted round in the same angular direction as that in which the planet was going; and this is expressed by saying that *the line of apses progresses.* If, after passing *c*, the disturbing force should again act for a little while,—at *e* for instance,—the recess of the planet from the sun would be diminished; its path would be more nearly perpendicular to the radius vector; and, therefore, the inclination of the path would be such as corresponds to a smaller distance from perihelion than the planet really has; that is, when the planet leaves *e*, the inclination of its path to the radius vector is greater than it would have been if the planet had continued to move in the orbit *c d b*, but is the same as if its perihelion had been at some such situation as *f*, supposing no disturbing force to act. Now let the disturbing force cease entirely to act, and the planet, which at *e* is moving as if it had come from the perihelion *f*, will continue to move as if it had come from the perihelion *f*; it will proceed, therefore, to describe an elliptic orbit in which *f* S *g* is the line of apses: the line of apses has been twisted round in the same direction as before, or the line of apses has still progressed. The effect, then, of a disturbing force directed to the central body before and after passing the perihelion, is to make the line of apses progress.*

Fig. 7.

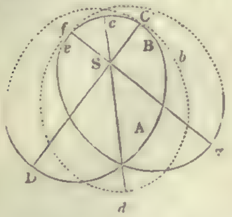
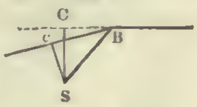


Fig. 7*



(51.) In the same manner, it will be seen, that the effect of a disturbing force, directed from the central body before and after passing the perihelion, is to make the line of apses regress.

(52.) The motion of the planet, subject to such forces as we have mentioned, would be *nearly* the same as if it was revolving in an elliptic orbit, and this elliptic orbit was at the same time revolving round its focus, turning in the same direction as that in which the planet goes round, and always carrying it on its circumference. And this is the easiest way of representing to the mind the *general effect* of this motion; the *physical cause* is to be sought in such explanations as that above.

(53.) (VI.) Suppose a disturbing force directed to the centre, to act upon the planet when it is near aphelion. As the planet is going towards aphelion it is receding from the sun. The effect of the disturbing force is to diminish the rate of recess from the sun; and, therefore, to increase the inclination of the planet's path to the radius vector. The aphelion is the place where the planet's path is perpendicular to the radius vector. The effect of the disturbing force, then, which increases the inclination of the planet's path to the radius vector, will be to make that path perpendicular to the radius vector sooner than if the disturbing force had not acted. That is, the planet will be at aphelion sooner than it would have been if no disturbing force had acted. The aphelion has, as it were, gone backwards to meet the planet. If the disturbing force should entirely cease, the planet will move in an elliptic orbit, of which this new aphelion would be the permanent aphelion. The line passing through the aphelion has, therefore, twisted in a direction opposite to the planet's motion, or *the line of apses has regressed.* After passing aphelion, if the disturbing force still continues to act, the planet's approach to the sun will be quickened by the disturbing force; and, therefore, after some time, the planet's rate of approach will be greater than that corresponding, in an undisturbed orbit, to its actual distance from aphelion, and will be equal to that corresponding in an undisturbed orbit to a greater distance from aphelion. If, now, the disturbing force ceases, the planet, moving as if it came in an undisturbed orbit from an imaginary aphelion, will continue to move as if it came from that imaginary aphelion; and that imaginary aphelion having been at a greater distance behind the planet than the real aphelion, its place will be represented by saying that the line of apses has still regressed. The effect, then, of a disturbing force directed to the central body, before and after passing aphelion, is to make the line of apses regress.

(54.) In the same manner it will be seen, that the effect of a disturbing force, directed from the central body, before and after passing the aphelion, is to make the line of apses progress.

(55.) (VII.) Since a disturbing force, directed to the central body, or one directed from the central body, produces opposite effects with regard to the motion of the line of apses, according as it acts near perihelion or near aphelion, it is easy to perceive that there must be some place between perihelion and aphelion, where the disturbing force, directed to the central body, will produce no effect on the position of the line of apses. It is found by accurate investigation, that this point is the place where the radius vector is perpendicular to the line of apses.*

(56.) (VIII.) The effects mentioned above are greatest when the excentricity is small. Let us compare the two orbits A C B in *fig.* 8 and A C B in *fig.* 9, in one of which the excentricity is great and in the other small: suppose the disturbing force to act for a short time at the perihelion C, and to be nearly equal in the two orbits, so as to deflect the new path C *d* from the old orbit C B by equal angles in

Fig. 8.

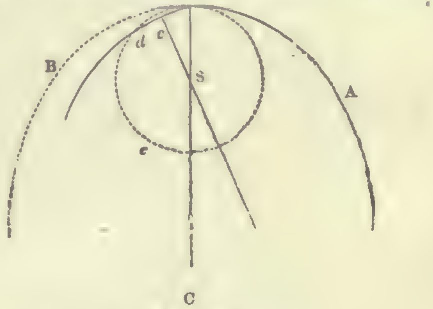
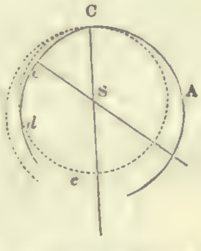


Fig. 9.



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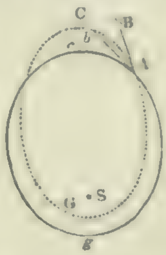
* This result, and those which follow immediately, may be inferred from the construction in Newton's 'Principia,' book i., sect. 3, prop. xvii. If we assume (as we suppose in all these investigations) the excentricity to be small, the disturbing force directed to the sun will not sensibly alter the planet's velocity, but will change the direction of its path at P, the place of action (in Newton's figure); the length of P H, therefore, will not be altered (since that length depends only on the velocity), but its position will be altered, the position of P H being determined by making the angle R P H equal to the supplement of R P S. On trying the effects of this in different positions of P, and observing that the immediate effect of a disturbing force directed to the centre is to increase the rate of approach, or to diminish the rate of receding, and that the effect of a force directed from the centre is the opposite, all the cases in the text will be fully explained.

* To the reader who is familiar with Newton's 'Principia,' sect. 3, the following demonstration will be sufficient: The disturbing force, which is entirely in the direction of the radius vector, will not alter the area described in a given time, and, therefore, will not alter the *latus rectum* (to the square root of which the area is proportional). But half the *latus rectum* of the undisturbed orbit is the radius vector at the supposed place of action of the disturbing force (since that radius vector is supposed perpendicular to the major axis). Therefore, half the *latus rectum* of the new orbit is the radius vector at the point in question; and, consequently, the radius vector, at the point in question, is perpendicular to the major axis in the new orbit; but it was so in the undisturbed orbit; and, therefore, the major axes in the new orbit and the undisturbed orbit coincide.

the two cases; with centre S describe the circle C *d e*. Then it is evident that the very excentric orbit C B in *fig.* 8 is widely separated from the circle C *d e*, and therefore, when it is bent through a given angle to the position C *d*, it will intersect the circle at a point *d* not distant from C. In *fig.* 9, on the contrary, the orbit C B is not widely separated from the circle, and therefore, when it is bent through a given angle, its intersection *d* will be distant from C. Now the new perihelion *c* will be found, in both cases, by bisecting C *d*; and, therefore, its change of position in *fig.* 8, where the orbit is very excentric, is much less than in *fig.* 9, where the excentricity is small. Or we may state it thus: The alteration of the place of perihelion, or aphelion, depends on the proportion which the alteration in the approach or recess produced by the disturbing force bears to the whole approach or recess; and is therefore greatest when the whole approach or recess is least; that is, when the orbit is little excentric.

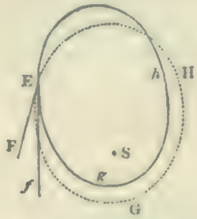
(57.) (IX.) To judge of the effect which a disturbing force, directed to the sun, will produce on the excentricity of a planet's orbit, let us suppose the planet to have left its perihelion, and to be moving towards aphelion, and, consequently, to be receding from the sun, and now let the disturbing force act for a short time. This will cause it to recede from the sun more slowly than it would have receded without the action of the disturbing force; and consequently, the planet, without any material alteration in its velocity,—and, therefore, without any material alteration in the major axis of its orbit (28),—will be moving in a path more inclined to the radius vector than if the disturbing force had not acted. The planet may, therefore, be considered as projected from the point A, *fig.* 10, in the direction A *b* instead of A B, in which it was moving; and, therefore, instead of describing the orbit A C G, in which it was moving before, it will describe an orbit A *c g*, more resembling a circle, or less excentric than before. The effect, therefore, of a disturbing force directed to the centre, while a planet is moving from perihelion to aphelion, is to diminish the excentricity of the orbit.

Fig. 10.



(58.) If we suppose the planet to be moving from aphelion to perihelion, it is approaching to the sun; the disturbing force directed to the sun makes it approach more rapidly; its path is therefore less inclined to the radius vector than it would have been without the disturbing force; and this effect may be represented by supposing that at E, *fig.* 11, instead of moving in the direction E F in which it was moving, the planet is projected in the direction E *f*. Instead therefore of describing the ellipse E G H, in which it was moving before, it will describe such an ellipse as E *g h*, which is more excentric than the former. The effect therefore of a disturbing force directed to the centre, while a planet is moving from aphelion to perihelion, is to increase the excentricity of the orbit.

Fig. 11.



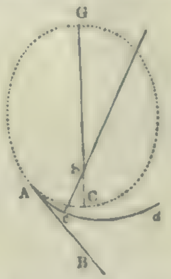
(59.) In a similar manner it will appear, that the effect of a disturbing force, directed from the centre, is to increase the excentricity as the planet is moving from perihelion to aphelion, and to diminish it as the planet moves from aphelion to perihelion.

(60.) (X.) Let us now lay aside the consideration of a force acting in the direction of the radius vector, and consider the effect of a force acting perpendicularly to the radius vector, in the direction in which the planet is moving. And first, its effect on the position of the line of apses.

(61.) If such a force act at one of the apses, either perihelion or aphelion, for a short time, it is clear that its effect will be represented by supposing that the velocity at that apse is suddenly increased, or that the velocity with which the planet is projected from perihelion is greater than the velocity with which it would have been projected if no disturbing force had acted. This will make no difference in the position of the line of apses; for with whatever velocity the planet is projected, if it is projected in a direction perpendicular to the radius vector (which is implied in our supposition, that the place where the force acts was an apse in the old orbit), the place of projection will infallibly be an apse in the new orbit: and the line of apses, which is the line drawn from that point through the sun, will be the same as before.

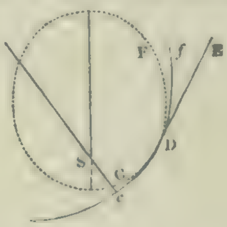
(62.) But if the force act for a short time before the planet reaches the perihelion, its principal * effect will be to increase its velocity; the sun's attraction will therefore have less power to curve its path (25); the new orbit will be, in that part, exterior to the old one. In *fig.* 12, we must therefore suppose that the planet, after leaving A, where the force has acted to accelerate its motion, instead of describing the orbit A C G, proceeds to describe the orbit A *c d*, which at A has the same direction (or has the same tangent A B) as the orbit A C G. It is plain now that *c* is the part nearest to the sun, or *c* is the perihelion: and it is evident here, that the line of apses has altered its position from S C to S *c*, or has twisted in a direction opposite to the angular motion of the planet, or has regressed.

Fig. 12.



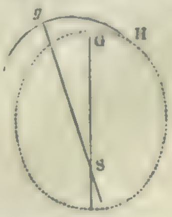
(63.) If the force act for a short time after the planet has passed perihelion, as at D, in *fig.* 13, the planet's velocity is increased there, and the path described by the planet is D *f*, instead of D F, having the same direction at D (or having the same tangent D E), but less curved, and therefore exterior to D F. If now we conceive the planet to have received the actual velocity with which it is moving in D *f*, from moving without disturbance in an elliptic orbit *c* D *f* (which is the orbit that it will now proceed to describe, if no disturbing force continues to act), it is evident that the part *c* D must be described with a greater velocity than C D, inasmuch as the velocity at D from moving in *c* D is greater than the velocity from moving in C D; *c* D is therefore less curved than C D, and therefore exterior to it (since it has the same direction at D); and then the perihelion is some point in the position of *c*, and the line of apses has changed its direction from S C to S *c*, or has twisted round in the same direction in which the planet is moving, or has progressed.

Fig. 13.



(64.) If the force act for a short time before passing the aphelion, it will be seen in the same manner that the line of apses is made to progress. It is only necessary to consider that (as before) the new orbit has the same direction at the point H, *fig.* 14, where the force has acted, as the old one, but is less curved, and therefore exterior to it; and the aphelion, or point most distant from the sun, is *g* instead of G, and the position of the line of apses has shifted from S G to S *g*. If the force act after the planet has passed the aphelion, as at K, *fig.* 15, the orbit in which we must conceive the planet to have come, in order to have the increased velocity, must be *g* K exterior to G K; the point most

Fig. 14.



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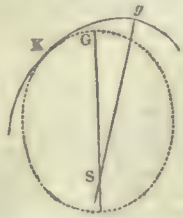
* It is supposed here, and in all our investigations, that the excentricity of the orbit is small, and, consequently, that a force perpendicular to the radius vector produces nearly the same effect as a force acting in the direction of a tangent to the ellipse.

distant from the sun must be g instead of G, and the line of apses must have changed from S G to S g, or must have regressed.

Fig. 15.



(65.) Collecting these conclusions,* we see that, if a disturbing force act perpendicularly to the radius vector, in the direction in which the planet is moving, its action, while the planet passes from perihelion to aphelion, causes the line of apses to progress; and its action, while the planet passes from aphelion to perihelion, causes the apses to regress.

(66.) By similar reasoning, if the direction of the disturbing force is opposite to that in which the planet is moving, its action, while the planet passes from perihelion to aphelion, causes the line of apses to regress, and while the planet passes from aphelion to perihelion causes the apses to progress.

(67.) (XI.) For the effect on the excentricity: suppose the disturbing force, increasing the velocity, to act for a short time at perihelion; the effect is the same as if the planet were projected from perihelion with a greater velocity than that which would cause it to describe the old orbit. The sun's attraction therefore will not be able to pull it into so small a compass as before; and at the opposite part of its orbit, that is, at aphelion, it will go off to a greater distance than before; but as it is moving without disturbance, and, therefore, in an ellipse, it will return to the same perihelion. The perihelion distance therefore remaining the same, and the aphelion distance being increased, the inequality of these distances is increased, and the orbit therefore is made more excentric. Now, suppose the force increasing the velocity to act at aphelion. Just as before, the sun's attraction will be unable to make the planet describe an orbit so small as its old orbit, and the distance at the opposite point (that is, at perihelion) will be increased; but the planet will return to the same aphelion distance as before. Here, then, the inequality of distances is diminished, and the excentricity is diminished.

(68.) Thus we see that a disturbing force, acting perpendicularly to the radius vector, in the direction of the planet's motion, increases the excentricity if it acts on the planet near perihelion, and diminishes the excentricity if it acts on the planet near aphelion. And, similarly, if the force acts in the direction opposite to that of the planet's motion, it diminishes the excentricity by acting near perihelion, and increases it by acting near aphelion.

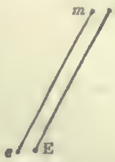
(69.) (XII.) In all these investigations, it is supposed that the disturbing force acts for a very short time, and then ceases. In future, we shall have to consider the effect of forces, which act for a long time, changing in intensity, but not ceasing. To estimate their effect we must suppose the long time divided into a great number of short times; we must then infer, from the preceding theorems, how the elements of the *instantaneous ellipse* (43) are changed in each of these short times by the action of the force, which is then disturbing the motion; and we must then recollect, that the instantaneous ellipse, at the end of the long time under consideration, will be the same as the permanent ellipse in which the planet will move. if the disturbing force then ceases to act (43), and that it will, at all events, differ very little from the curve described in the next revolution of the planet, even if the disturbing force continue to act. (41.)

SECTION IV.—*On the Nature of the Force disturbing a Planet or Satellite, produced by the Attraction of other Bodies.*

(70.) Having examined the effects of disturbing forces upon the elements of a planet's or satellite's orbit, we have now to inquire into the kind of the disturbing force which the attraction of another body produces. The inquiry is much simpler than might at first sight be expected; and this simplicity arises, in part, from the circumstance that (as we have mentioned in (6)) the attraction of a planet upon the sun is the same as its attraction upon another planet, when the sun and the attracted planet are equally distant from the attracting planet.

(71.) First, then, we have to remark, that the disturbing force is not the whole attraction. The sun, for instance, attracts the moon, and disturbs its elliptic motion round the earth; yet the force which disturbs the moon's motion is not the whole attraction of the sun upon the moon. For the effect of the attraction is to move the moon from the place where it would otherwise have been; but the sun's attraction upon the earth also moves the earth from the place where it would otherwise have been; and if the alteration of the earth's place is exactly the same as the alteration of the moon's place, the relative situation of the earth and moon will be the same as before. Thus, if, in *fig.* 16, any attraction carries the earth from E to e, and carries the

Fig. 16.



moon from M to m, and if E e is equal and parallel to M m, then $e\,m$, which is the distance of the earth and moon, on the supposition that the attraction acts on both, is equal to E M, which is their distance, on the supposition that the attraction acts on neither; and the line $e\,m$, which represents the direction in which the moon is seen from the earth, if the attraction acts on both, is parallel to E M, which represents the direction in which the moon is seen from the earth, if the attraction acts on neither. The distance therefore of the earth and moon, and the direction in which the moon is seen from the earth, being unaltered by such a force, their relative situation is unaltered. An attraction, therefore, which acts equally, and in the same direction, on both bodies, does not disturb their relative motions.

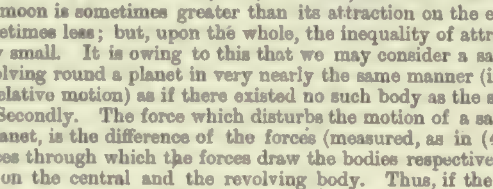
From this we draw the two following important conclusions:—

(72.) Firstly. A planet may revolve round the sun, carrying with it a satellite; and the satellite may revolve round the planet in nearly the same manner as if the planet was at rest. For the attraction of the sun on the planet is nearly the same as the attraction of the sun on the satellite. It is true that they are not exactly the same, and the effects of the difference will soon form an important subject of inquiry; but they are, upon the whole, very nearly the same. The moon is sometimes nearer to the sun than the earth is, and sometimes farther from the sun; and, therefore, the sun's attraction on the moon is sometimes greater than its attraction on the earth, and sometimes less; but, upon the whole, the inequality of attractions is very small. It is owing to this that we may consider a satellite as revolving round a planet in very nearly the same manner (in respect of relative motion) as if there existed no such body as the sun.

(73.) Secondly. The force which disturbs the motion of a satellite, or a planet, is the difference of the forces (measured, as in (4), by the spaces through which the forces draw the bodies respectively) which act on the central and the revolving body. Thus, if the moon is between the sun and the earth, and if the sun's attraction in a certain time draws the earth 200 inches, and in the same time draws the moon 201 inches, then the real disturbing force is the force which would produce in the moon a motion of one inch from the earth.

(74.) In illustrating the second remark, we have taken the simplest case that can well be imagined. If, however, the moon is in any other situation with respect to the earth, some complication is introduced. Not only is the moon's distance from the sun different from the earth's distance, (which according to (9) produces an inequality in the attractions upon the earth and moon,) but also the direction in which the attraction acts on the earth is different from the direction in which it acts on the moon, (inasmuch as the attraction always acts in the direction of the line drawn from the attracted body to the attracting body; and the lines so drawn from the earth and moon to the sun are in different directions.) The same applies in every respect to the perturbation which one planet produces in the motion of a second planet round the sun, and which depends upon the difference in the first planet's attractions upon the sun and upon the second planet. To overcome this difficulty we must have recourse to geometrical considerations. In *fig.* 17, let B_1 be a body revolving about A, and let C be another body whose attraction disturbs the motion of B_1 round A The attraction of C will in a certain time draw A to a; it will in the same time draw B_1 to b_1. Make $B_1\,d_1$ equal and parallel to A a; then $a\,d_1$ will be equal and parallel to A B_1. Now if the force upon B_1 were such as to draw it to d_1, the motion of B_1 round A would not be disturbed by that force. But the force upon B_1 is really such as to draw it to b_1. The real disturbing force then may be represented as a force which draws the revolving body from d_1 to b_1. If, instead of supposing the revolving body to be at B_1 we suppose it at B_2, and if the attraction of C would draw it through $B_2\,b_2$ while it draws A through A a, then (in the same manner, making $B_2\,d_2$ equal and parallel to A a) the real disturbing force may be represented by a force which in the same time would draw B_2 through $d_2\,b_2$.

Fig. 17.



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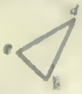
* These conclusions, and those that follow, will be easily inferred from Newton's construction, Prop. XVII., by observing, that an increase of the velocity increases the length of P H in Newton's figure without altering its position.

(75.) Both the magnitude and the direction of this force are continually varying, and we must, if possible, find a convenient way of representing it. We shall have recourse here to the "compositon of motion." In *fig.* 18, if $d\,b$ represent the space through which a force has drawn a body in a certain time, the same effect may be produced by two forces of which one would in the same time draw the body from d to e, and the other would in the same time draw the body from e to b. And this is true whatever be the directions and lengths of $d\,e$ and $e\,b$, provided that with $d\,b$ they form a triangle. To accommodate the investigations of this Section to those of Section III., we will suppose $d\,e$ perpendicular to the radius vector, and $e\,b$ parallel to the radius vector. In *fig.* 17, draw $d\,e$ perpendicular to A B or $a\,d$, and $e\,b$ parallel to A B or $a\,d$; and now we can say: the disturbing force produced by the attraction of C is a force represented by $d\,e$ perpendicular to the radius vector, and a force represented by $e\,b$ in the direction of the radius vector.

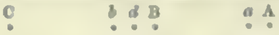
Fig. 18.



(76.) We now want nothing but estimations of the magnitudes of these forces in order to apply the investigations of Section III. For the present we shall content ourselves with pointing out some of the most interesting cases.

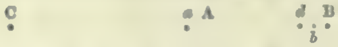
(77.) I. Let the disturbing body be exterior to the orbit of the disturbed body: (this applies to the disturbance of the moon's motion produced by the sun's attraction, the disturbance of the earth's motion by Jupiter's attraction, the disturbance of the motion of Venus by the earth's attraction, &c.:) and first, let the revolving body B be between the disturbing body C and the central body A (as in *fig.* 19.). If the attraction of C will in a certain time draw A to a, it will in the same time draw B to b, where B b is much greater than A a. Take B d equal to A a, then $d\,b$ is the effect of the disturbing force, which tends to draw B further from A. In this case then, the disturbing force is entirely in the direction of the radius vector, and directed *from* the central body. This is the greatest disturbing force that can be produced by C.

Fig. 19.



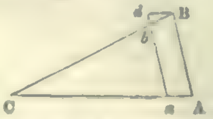
(78.) II. Let C A B (*fig.* 20) be in the same straight line, but let B be on the side of A, opposite to C. In this case B b is less than A a; and if B d is taken equal to A a, the disturbing force represented by $d\,b$ will be entirely in the direction of the radius vector, and directed from the central body. This case is particularly deserving of the reader's consideration, as the *effectual disturbing* force is exactly opposite to the attraction which C actually exerts upon B.

Fig. 20.



(79.) III. The disturbing force in the case represented in *fig.* 19, is much greater than that in the case of *fig.* 20, except C be very distant. Thus, suppose A B to be half of A C. In the first case, the attraction upon B (by the law of gravitation) is four times as great as the attraction upon A, and therefore the disturbing force (which is the difference of the forces on A and B) is three times as great as the attraction upon A. In the second case, the distance of B is $\frac{3}{2}$ of the distance of A, and therefore the attraction upon B is $\frac{4}{9}$ of the attraction upon A, and the disturbing force is $\frac{5}{9}$ of the attraction upon A. The disturbing force in the first case is, therefore, greater than in the second case, in the proportion of 3 to $\frac{5}{9}$, or 27 to 5. This remark applies to nearly all the cases of planetary disturbance where the disturbing planet is exterior to the orbit of the disturbed planet, the ratio between these distances from the sun being a ratio of not very great inequality. But it scarcely applies to the moon. For the sun's distance from the earth is nearly 400 times the moon's distance: consequently when the moon is between the sun and the earth, the attraction of the sun on the moon is $(\frac{400}{399})^2 \times$ the attraction of the sun on the earth, or $\frac{160000}{159201}$ parts of the sun's attraction on the earth, and the disturbing force therefore is $\frac{799}{159201}$ parts of the sun's attraction on the earth; but when the moon is on that side farthest from the sun, the sun's attraction on the moon is $(\frac{400}{401})^2$ or $\frac{160000}{160801}$ parts of the sun's attraction on the earth, and the disturbing force is $\frac{801}{160801}$ parts of the sun's attraction on the earth, which is very little less than the former. The effects of the difference are, however, sensible.

Fig. 21.



(80.) IV. Suppose B, *fig.* 21, to be in that part of its orbit which is at the same distance from C as the distance of A from C. The attraction of C upon the two other bodies, whose distances are equal, will be equal, but not in the same direction. B b, therefore, will be equal to A a. But since C B is also equal to C A, it is evident that $a\,b$ will be parallel to A B, and therefore b will be in the line $a\,d$. Consequently in this case also the disturbing force will be entirely in the direction of the radius vector; but here, unlike the other cases, the disturbing force is directed *towards* the central body. The magnitude of the disturbing force bears the same proportion to the whole attraction on A which $b\,d$ bears to B b, or A B to A C. Thus, in the first numerical instance taken above, the disturbing force in this part of the orbit is $\frac{1}{2}$ of the attraction on A: and in the second numerical instance, the disturbing force is $\frac{1}{400}$ of the attraction on A. It is important to observe that in both instances the disturbing force, when wholly directed *to* the centre, is much less than either value of the disturbing force when wholly directed *from* the centre: in the latter instance it is almost exactly one-half.

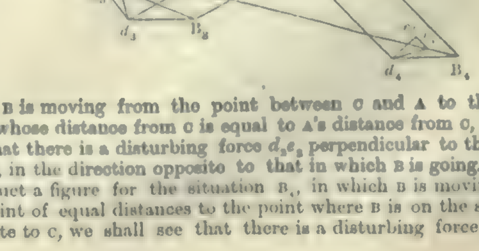
81. When the disturbing body is distant, the point of the orbit which we have here considered is very nearly that determined by drawing A B perpendicular to C A.

(82.) V. When C is distant (as in the case of the moon disturbed by the sun), the disturbing forces mentioned in (III.) and (IV.) are nearly proportional to the distance of the moon from the earth. For the force mentioned in (IV.) this is exactly true, whether C be near or distant, because (as we have found) the disturbing force bears the same proportion to the whole attraction on A which A B bears to A C. With regard to the force mentioned in (III.): if we suppose the moon's distance from the earth to be $\frac{1}{400}$ of the sun's distance, the disturbing force when the moon is between the earth and the sun is $\frac{799}{159201}$ parts of the sun's attraction on the earth, or nearly $\frac{1}{200}$th part. But if we suppose the moon's distance from the earth to be $\frac{1}{200}$th of the sun's distance, the attraction on the moon (when between the earth and the sun) would be $(\frac{200}{199})^2$ or $\frac{40000}{39601}$ parts of the attraction on the earth; the disturbing force or the difference of attractions on the earth and moon, would be $\frac{399}{39601}$, or nearly $\frac{1}{100}$th part of the sun's attraction on the earth. Thus, on doubling the moon's distance from the earth, the disturbing force is nearly doubled: and in the same manner, on altering the distance in any other proportion, we should find that the disturbing force is altered in nearly the same proportion.

(83.) VI. If, while the moon's distance from the earth is not sensibly altered, the earth's distance from the sun is altered, the disturbing force is diminished very nearly in the same ratio in which the cube of the sun's distance is increased. For if the sun's distance is 400 times the moon's distance, and the moon between the earth and the sun, we have seen that the disturbing force is nearly $\frac{1}{200}$th part of the sun's attraction on the earth *at that distance of the sun.* Now, suppose the sun's distance from the earth to be made 800 times the moon's distance, or twice the former distance: the sun's distance from the moon will be 799 times the moon's distance, or $\frac{799}{400}$ parts of the sun's former distance from the earth; the attractions on the earth and moon respectively will be $\frac{1}{4}$ and $\frac{160000}{638401}$ parts of the former attraction on the earth: and the disturbing force, or the difference between these, will be $\frac{1599}{2553604}$, or nearly $\frac{1}{1600}$th part of the former attraction of the earth. Thus, on doubling the sun's distance, the disturbing force is diminished to $\frac{1}{8}$th part of its former value; and a similar proposition would be found to be true if the sun's distance were altered in any other proportion.

(84.) VII. Suppose B to have moved from that part of its orbit where its distance from C is equal to A's distance from C, towards the part where it is between A and C. Since at the point where B's distance from C is equal to A's distance from C, the disturbing force is in the direction of the radius vector, and directed *towards* A, and since at the point where B is between A and C, the disturbing force is in the direction of the radius vector, but directed *from* A, it is plain that there is some situation of B, between these two points, in which there is no disturbing force at all in the direction of the radius vector. On this we shall not at present speak further: but we shall remark that there is a disturbing force perpendicular to the radius vector, at every such intermediate point. This will be easily seen from the second case of *fig.* 17. On going through the reasoning in that place it will appear that, between the two points that we have mentioned, there is always a disturbing force d_2e_2 perpendicular to the radius vector, and in the same direction in which the body is going. If now we construct a similar figure for the situation B_3, *fig.* 22, in which B is moving from the point between C and A to the other point whose distance from C is equal to A's distance from C, we shall find that there is a disturbing force d_3e_3 perpendicular to the radius vector, in the direction opposite to that in which B is going. If we construct a figure for the situation B_4, in which B is moving from the point of equal distances to the point where B is on the side of A opposite to C, we shall see that there is a disturbing force perpen-

Fig. 22.

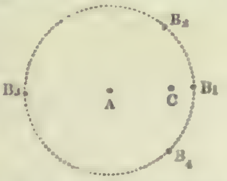


dicular to the radius vector, in the same direction in which B is going; and in the same manner, for the situation B_1 in *fig.* 17, where B is moving from the point on the side of A opposite C to the next **point of equal distances, there is a disturbing force perpendicular** to the radius vector, in the direction opposite to that in which B is going.

(85.) The results of all these cases may be collected thus. The disturbing body being exterior to the orbit of the revolving body, there is a disturbing force in the direction of the radius vector only, directed *from* the central body, at the points where the revolving body is on the same side of the central body as the disturbing body, or on the opposite side (the force in the former case being the greater), and **directed *to* the central body, at each of the places where the distance** from the disturbing body is equal to the distance of the central body from the disturbing body. The force directed to the central body at the latter points, is, however, much less than the force directed from it at the former. Between the adjacent pairs of these four points there are four other points, at which the disturbing force in the direction of the radius vector is nothing. But while the revolving body is moving from one of the points, where it is on the same side of the central body as the disturbing body, or on the opposite side, to one of the equidistant points, there is always a disturbing force perpendicular to the radius vector tending to retard it; and while it is moving from one of the equidistant points to one of the points on the same side of the central body as the disturbing body, or the opposite, there is a disturbing force perpendicular to the radius vector tending **to accelerate it.**

(86.) VIII. Now, let the disturbing body be supposed interior to the orbit of the revolving body (as, for instance, when Venus disturbs the motion of the earth). **If B is in the situation B_1, *fig.* 23, the**

Fig. 23.



attraction of C draws A strongly towards B_1, and B_1 strongly towards A, and, therefore, there is a very powerful disturbing force drawing B_1 towards A. If B is in the situation B_3, the attraction of C draws A strongly from B_3, and draws B_3 feebly towards A; therefore, there is a small disturbing force drawing B_1 from A. At some intermediate points the disturbing force in the direction of the radius vector is nothing. With regard to the disturbing force perpendicular to the radius **vector: if A C is greater than ½ A B_1, it will** be possible to find two points, B_2 and B_4, whose distance from C is **equal to the** distance of A from C, and there the disturbing force perpendicular to the radius vector is nothing (or the whole disturbing force is in the direction of the radius vector). While B moves from the position B_1 to B_2, it will be seen by such reasoning as that of (75) and (84), that the disturbing force, perpendicular to the radius vector, retards B's motion; while B moves from B_2 to B_3, it **accelerates B's motion; while B moves from B_3 to B_4 it retards B's motion; and while B moves from B_4 to B_1, it accelerates B's motion. But if A C is less than ½ A B_1, there are no such points, B_2 B_4, as we have spoken of; and the disturbing force perpendicular to the radius vector, accelerates B as it moves from B_1 to B_3, and retards B as it moves from B_3 to B_1.**

We shall now proceed to apply these general principles to particular cases.

SECTION V.—*Lunar Theory.*

(87.) The distinguishing feature in the Lunar Theory is the general simplicity occasioned by the great distance of the disturbing body (the sun alone producing any sensible disturbance), in proportion to the moon's distance from the earth. The magnitude of the disturbing body renders these disturbances very much more conspicuous than any others in the solar system; and, on this account, as well as for the accuracy with which they can be observed, these disturbances have, **since the invention of the Theory of Gravitation, been considered the best tests of the truth of the theory.**

Some of the disturbances are independent of the excentricity of the **moon's orbit; others depend, in a very remarkable manner, upon the excentricity. We shall commence with the former.**

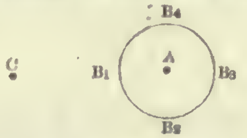
(88.) The general nature of the disturbing force on the moon may be thus stated. (See (77) to (86).) When the moon is either at the point between the earth and sun, or at that opposite to the sun (both which points are called syzygies), the force is entirely in the direction of the radius vector, and directed from the earth. When the moon is (very nearly) in the situations at which the radius vector is perpendicular to the line joining the earth and sun (both which points are called quadratures), the force is entirely in the direction of the radius vector, and directed to the earth. At certain intermediate points there is no disturbing force in the direction of the radius vector. Except at syzygies and quadratures, there is always a force perpendicular to the radius vector, such as to retard the moon while she goes from syzygy to quadrature, and to accelerate her while she goes from quadrature to **syzygy.**

(89.) I. As the disturbing force, in the direction of the radius vector directed from the earth, is greater than that directed to the earth, we may consider that, upon the whole, the effect of the disturbing force is to diminish the earth's attraction. Thus the moon's mean distance from the earth is less (see (46)) than it would have been with the same periodic time, if the sun had not disturbed it. The force perpendicular to the radius vector sometimes accelerates the moon, and sometimes retards it, and, therefore, produces no **permanent effect.**

(90.) II. But the sun's distance from the earth is subject to alteration, because the earth revolves in an elliptic orbit round the sun. Now, we have seen (83) that the magnitude of the disturbing force is inversely proportional to the cube of the sun's distance; and, consequently, it is sensibly greater when the earth is at perihelion than when at aphelion. Therefore, while the earth moves from perihelion to aphelion, the disturbing force is continually diminishing; and while it moves from aphelion to perihelion, the disturbing force is constantly increasing. Referring then to (47) it will be seen, that in the former of these times the moon's orbit is gradually diminishing, and that in the latter it is gradually enlarging. And though this alteration is not great (the whole variation of dimensions, from greatest to least, being less than $\frac{1}{5000}$, the effect on the angular **motion (see (49)) is very considerable; the anguar velocity** becoming quicker in the former time and slower in the latter; so that while the earth moves from perihelion to aphelion, the moon's angular motion is constantly becoming quicker, and while the earth **moves from aphelion to perihelion the moon's angular motion is constantly becoming slower. Now, if the moon's mean motion is determined by comparing two places observed at the interval of many years, the angular motion so found is a mean between the greatest and least. Therefore, when the earth is at perihelion, the moon's angular motion is slower than its mean motion; and when the earth is at aphelion, the moon's angular motion is quicker than its mean motion.** Consequently, **while the earth is going from perihelion to aphelion, the moon's true place is always behind its** mean place (as during the first half of that period the moon's true place is dropping behind the mean place, and during the latter half is gaining again the quantity which it had dropped behind); and while the earth is going from aphelion to perihelion, the moon's true place is always before its mean place. This inequality is called the moon's *annual equation*; it was discovered by Tycho Brahé from observation, about 1590; and its greatest value is about 10′, by which the true place is sometimes before and sometimes **behind the mean place.**

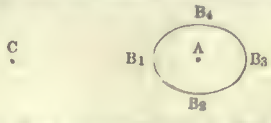
(91.) III. The disturbances which are periodical in every revolution of the moon, and are independent of excentricity, may thus be investigated. Suppose the sun to stand still for a few revolutions of the moon (or rather suppose the earth to be stationary), and let us inquire in what kind of orbit, symmetrical on opposite sides, the sun can move. It cannot move in a circle: for the force perpendicular to the radius vector retards the moon as it goes from B_1 to B_2, *fig.* 24,

Fig. 24.



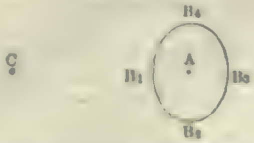
and its velocity is therefore less at B_2 than at B_1, and on this account (supposing the force directed to A at B_2 equal to the force directed to A at B_1), the orbit would be more curved at B_2 than at B_1. But the force directed to A at B_2 is much greater than at B_1 (see (88)); and on this account the orbit would be still more curved at B_2 than at B_1; whereas, in a circle, the curvature is everywhere the same. The orbit cannot therefore be circular. Neither can it be an oval with the earth in its centre, and with its longer axis passing through the sun, as *fig.* 25; for the velocity being small at B_2 (in consequence

Fig. 25.



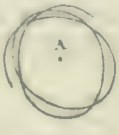
of the disturbing force perpendicular to the radius vector having retarded it) while the earth's attraction is great (in consequence of the nearness of B_2), and increased by the disturbing force in the radius vector directed towards the earth, the curvature at B_2 ought to be much greater than at B_1, where the velocity is great, the moon far off, and the disturbing force directed from the earth. But, on the contrary, the curvature at B_2 is much less than at B_1; therefore, this form of orbit is not the true one. But if the orbit be supposed to be oval, with its shorter axis directed towards the sun, as in *fig.* 26, all the conditions will be satisfied. For the velocity at B_2 is diminished by the disturbing force having acted perpendicularly to the radius vector, while the moon goes from B_1 to B_2; and though, the distance from A being greater, the earth's attraction at B_2 will be less than the attraction at B_1; yet, when increased by the disturbing force, directed to A at B_2, it will be very little less than the attraction diminished by the disturbing force at B_1. The diminution of velocity then at B_2 being considerable, and the diminution of force small, the curvature will be increased; and this increase of curvature, by proper choice of the proportions of the oval, may be precisely such as corresponds to the real difference of curvature in the different parts of the oval. Hence, such an oval may be described by the moon without alteration in successive revolutions.

Fig. 26.



(92.) We have here supposed the earth to be stationary with respect to the sun. If however we take the true case of the earth moving round the sun, or the sun appearing to move round the earth, we have only to suppose that the oval twists round after the sun, and the same reasoning applies. The curve described by the moon is then such as is represented in *fig.* 27. As the disturbing force, perpendicular to the radius vector, acts in the same direction for a longer time than in the former case, the difference in the velocity at syzygies and at quadratures is greater than in the former case, and this will require the oval to differ from a circle, rather more than if the sun be supposed to stand still.

Fig. 27.



(93.) If, now, in such an orbit as we have mentioned, the law of *uniform description of areas by the radius vector* were followed, as it would be if there were no force perpendicular to the radius vector, the angular motion of the moon near B_2 and B_4, *fig.* 26, would be much less than that near B_1 and B_3. But in consequence of the disturbing force, perpendicular to the radius vector (which retards the moon from B_1 to B_2, and from B_3 to B_4, and accelerates it from B_2 to B_3, and from B_4 to B_1), the angular motion is still less at B_2 and B_4, and still greater at B_1 and B_3. The angular motion therefore diminishes considerably while the moon moves from B_1 to B_2, and increases considerably while it moves from B_2 to B_3, &c. The mean angular motion, determined by observation, is less than the former and greater than the latter. Consequently, the angular motion at B_1 is greater than the mean, and that at B_2 is less than the mean; and therefore (as in (90),) from B_1 to B_2 the moon's true place is before the mean; from B_2 to B_3 the true place is behind the mean; from B_3 to B_4 the true place is before the mean; and from B_4 to B_1 the true place is behind the mean. This inequality is called the moon's *variation*; it amounts to about 32′, by which the moon's true place is sometimes before and sometimes behind the mean place. It was discovered by Tycho Brahé, from observation about 1590.

(94.) We have however mentioned, in (79), that the disturbing forces are not exactly equal on the side of the orbit which is next the sun, and on that which is farthest from the sun; the former being rather greater. To take account of the effects of this difference, let us suppose, that in the investigation just finished, we use a mean value of the disturbing force. Then we must, to represent the real case, suppose the disturbing force near conjunction to be increased, and that near opposition to be diminished. Observing what the nature of these forces is (77), (78), and (84), this amounts to supposing that near conjunction the force necessary to make up the difference is a force acting in the radius vector, and directed from the earth, and a force perpendicular to the radius vector, accelerating the moon before conjunction, and retarding her after it, and that near opposition the forces are exactly of the contrary kind. Let us then lay aside the consideration of all other disturbing forces, and consider the inequality which these forces alone will produce. As they are very small, they will not in one revolution alter the orbit sensibly from an elliptic form. What then must be the excentricity, and what the position of the line of apses that, with these disturbing forces only, the same kind of orbit may always be described? A very little consideration of (57), (58), and (68), will show, that unless the line of apses pass through the sun, the excentricity will either be increasing or diminishing from the action of these forces. We must assume therefore, as our orbit is to have the same excentricity at each revolution, that the line of apses passes through the sun. But is the perigee or the apogee to be turned towards the sun? To answer this question we have only to observe that the lines of apses must progress as fast as the sun appears to progress, and we must therefore choose that position in which the forces will cause progression of the line of apses. If the perigee be directed to the sun, then the forces at both parts of the orbit will, by (51), (54), (65), and (66), cause the line of apses to regress. This supposition, then, cannot be admitted. But if the apogee be directed to the sun, the forces at both parts of the orbit will cause it to progress; and by (56), if a proper value is given to the excentricity it will progress exactly as fast as the sun appears to progress. The effect, then, of the difference of forces of which we have spoken, is to elongate the orbit towards the sun, and to compress it on the opposite side. This irregularity is called the *parallactic inequality*.

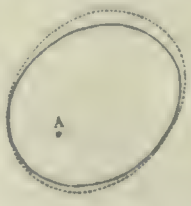
We shall shortly show, that if the moon revolved in such an elliptic orbit as we have mentioned, the effect of the other disturbing forces (independent of that discussed here) would be to make its line of apses progress with a considerable velocity. The force considered here, therefore, will merely have to cause a progression which, added to that just mentioned, will equal the sun's apparent motion round the earth. The excentricity of the ellipse, in which it could produce this smaller motion, will (56) be greater than that of the ellipse in which the same force could produce the whole motion. Thus the magnitude of the parallactic inequality is considerably increased by the indirect effect of the other disturbing forces.

(95.) The magnitude of the forces concerned here is about $\frac{1}{130}$th of those concerned in (91), &c.; but the effect is about $\frac{1}{11}$th of their effect. This is a striking instance of the difference of proportions, in forces and the effects that they produce, depending on the difference in their modes of action. The inequality here discussed is a very interesting one, from the circumstance that it enables us to determine with considerable accuracy the proportion of the sun's distance to the moon's distance, which none of the others will do, as it is found upon calculation that their magnitude depends upon nothing but the excentricities and the proportion of the periodic times, all which are known without knowing the proportion of distances.

(96.) The effect of this, it will be readily understood, is to be combined with that already found. [See the Note to (134).] The moon's orbit therefore is more flattened on the side farthest from the sun, and less flattened on the side next the sun, than we found in (91) and (92). The equable description of areas is scarcely affected by these forces. The moon's *variation* therefore is somewhat diminished near conjunction, and is somewhat increased near opposition.

(97.) It will easily be imagined, that if there is an excentricity in the moon's orbit, the effect of the *variation* upon that orbit will be almost exactly the same as if there were no excentricity.* Thus, supposing that the orbit without the disturbing force had such a form as the dark line in *fig.* 28, it will, with the disturbing force, have such a form as the dotted line in that figure. The same must be understood in many other cases of different inequalities which affect the motion of the same body.

Fig. 28.



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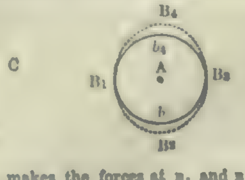
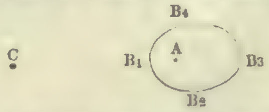
* As this general proposition is of considerable importance, we shall point out the nature of the reasoning by which (with proper alteration for different cases), the reader may satisfy himself of its correctness. The reason why, in *fig.* 29, the moon cannot describe the circle B_1, b_2, B_3, b_4, though it touches at B_1 and B_3, and the reason that it will describe the oval B_1, B_2, B_3, B , is, that the disturbing force makes the forces at B_1 and B_3 less than they would otherwise have been, and greater at B_2 and B_4 than they would otherwise have been; and the velocity is, by that part of the force perpendicular to the radius vector, made less at B_2 than it would otherwise have been. So that, unless we supposed it moving at B_1 with a greater velocity than it would have had undisturbed in the circle B_1, b_2, B_3, b_4, the great curvature produced by the great force and diminished velocity at B_2 would have brought it much nearer to A than the point B_2; but with this large velocity at B_1, it will go out further at B_4, and then the great curvature may make it pass exactly through B_3. In like manner, in *fig.* 30, if the velocity at B_1 were not greater than it would have had undisturbed in the ellipse B_1, b_2, B_3, b_4, the increased curvature at B_2, produced by the increased force and diminished velocity there, would have brought it much nearer to A than the point B_2; but with a large velocity at B_1 it will go out at B_2 further than it would otherwise have gone out, and then the increased force and diminished velocity will curve its course so much, that it may touch the elliptic orbit at B_3; and so on. The whole explanation, in

Fig. 29.



(98.) IV. We now proceed with the disturbances dependent on the excentricity: and first with the motion of the moon's perigee. In the first place, suppose that the perigee is on the same side as the sun. While the moon is near B_1, *fig.* 31, that is, near perigee, the

Fig. 31.



disturbing force is directed from A; and consequently by (51) the line of apses regresses. While the moon is near B_3, that is, near apogee, the disturbing force is also directed from A, and consequently by (54) the line of apses progresses. The question then now is, which is the greater, the regress, when the moon is near B_1, or the progress, when it is near B_3? To answer this we will remark, that if the disturbing force directed from A were inversely proportional to the square of the distance (and consequently less at B_3 than at B_1), it would amount to exactly the same as if the attraction of A were altered in a given proportion;[*] and in that case B would describe round A an ellipse, whose line of apses was invariable; or the progression produced at B_3 would be equal to the regression produced at B_1. But in fact the disturbing force at B_3 is to that at B_1 in the same proportion as A B_3 to A B_1, by (32); and therefore the disturbing force at B_3 is greater than that at B_1, and consequently much greater than that which would produce a progression equal to the regression produced at B_1; and therefore the effects of the disturbing force at B_3 predominate, and the line of apses progresses. The disturbing force directed to A in the neighbourhood of B_2 and B_4 scarcely produces any effect, as on one side of each of those points the effect is of one kind, and on the other side it is of the opposite kind (55).

(99.) The disturbing force directed from A, though the only one at B_1 and B_3, is not however the only one in the neighbourhood of B_1 and B_3. While the moon is approaching to B_1, the force perpendicular to the radius vector accelerates the moon, and therefore, by (65), as B_1 is the place of perigee, the line of apses regresses: when the moon has passed B_1 the force retards the moon, and therefore, by (66), the line of apses still regresses. But when the moon is approaching B_3, the force perpendicular to the radius vector accelerates the moon; and therefore, by (65) and (66), as B_3 is the place of apogee, the line of apses progresses; when the moon has passed B_3, the force retards the moon, and the line of apses still progresses. The question now is, whether the progression produced by the force perpendicular to the radius vector near B_3 will or will not exceed the regression produced near B_1? To answer this we must observe, that the rate of this progress or regress depends entirely upon the proportion[†] which the velocity produced by the disturbing force bears to the velocity of the moon; and since from B_2 to B_3, and from B_3 to B_4, the disturbing force is greater than that from B_4 to B_1, and from B_1 to B_2, and acts for a longer time (as by the law of equable description of areas, the moon is longer moving from B_2 to B_3 and B_4 than from B_4 to B_1 and B_2), and since the moon's velocity in passing through B_2, B_3, B_4, is less than her velocity in passing through B_4, B_1, B_2, it follows that the effect in passing through B_2, B_3, B_4, is much greater than that in passing through B_4, B_1, and B_2. Consequently, the effect of this force also is to make the line of apses progress.

(100.) On the whole, therefore, when the perigee is turned towards the sun, the line of apses progresses rapidly: And the same reasoning applies in every respect when the perigee is turned from the sun.

(101.) In the second place, suppose that the line of apses is perpendicular to the line joining the earth and sun. The disturbing force at both apses is now directed to the earth, and consequently by (50) and (53), while the moon is near perigee, the disturbing force causes the line of apses to progress, and while the moon is near apogee the disturbing force causes the line of apses to regress. Here, as in the last article, the effects at perigee and at apogee would balance if the disturbing force were inversely proportional to the square of the distance from the earth. But the disturbing force is really proportional to the distance from the earth; and therefore, as in (98), the effect of the disturbing force, while the moon is at apogee, preponderates over the other; and therefore the force directed to the centre causes the line of apses to regress.

(102.) We must also consider the force perpendicular to the radius vector. In this instance that force retards the moon while she is approaching to each apse, and accelerates her as she recedes from it. The effect is, that when the moon is near perigee the force causes the line of apses to progress, and when near apogee it causes the line of apses to regress (65) and (66). The latter is found to preponderate, by the same reasoning as that in (99). From the effect, then, of both causes, the line of apses regresses rapidly in this position of the line of apses.

(103.) It is important to observe here, that the motion of the line of apses would not, as in (56), be greater if the excentricity of the orbit were smaller; for, though the motion of the line of apses is greater *in proportion to the force which causes it* when the excentricity is smaller, yet, in the present instance, the force which causes it is itself proportional to the excentricity (inasmuch as it is the difference of the forces at perigee and apogee, which would be equal if there were no excentricity): so that if the excentricity were made less, the force which causes the motion of the line of apses would also be made less, and the motion of the line of apses would be nearly the same as before.

(104.) It appears, then, that when the line of apses passes through the sun, the disturbing force causes that line to progress; when the earth has moved round the sun, or the sun has appeared to move round the earth, so far that the line of apses is perpendicular to the line joining the sun and the earth, the line of apses regresses from the effect of the disturbing force; and at some intermediate position it may easily be imagined that the force produces no effect on it. It becomes now a matter of great interest to inquire, whether, upon the whole, the progression exceeds the regression. Now, the force perpendicular to the radius vector, considered in (99), is almost exactly equal to that considered in (102); so that the progression produced by that force when the line of apses passes through the sun, is almost exactly equal to the regression which it produces when the line of apses is perpendicular to the line joining the earth and sun; and this force may therefore be considered as producing no effect (except indirectly, as will be hereafter mentioned). But the force in the direction of the radius vector, tending from the earth in (98), is, as we have mentioned in (80), almost exactly double of that tending to the earth in (101), and therefore its effect predominates; and therefore, on the whole, the line of apses progresses. In fact, the progress, when the line of apses passes through the sun, is about 11° in each revolution of the moon; the regress, when the line of apses is perpendicular to the line joining the earth and sun, is about 9° in each revolution of the moon.

(105.) The progression of the line of apses of the moon is considerably

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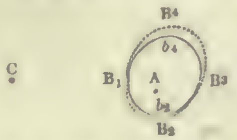
one case as much as in the other, depends entirely upon the difference of the forces in the actual case, from the forces, if the moon were not disturbed.

Fig. 30.



[*] The reasoning in the text may be more fully stated thus: If, with the original attractive force of the earth there be combined another force, directed from the earth, and always bearing the same proportion to the earth's original attraction, this combined force may be considered in two ways: 1st, As a smaller attraction, always proportional to the original attraction, or inversely proportional to the square of the distance. 2nd, As the original attraction, with a force superadded, which may be treated as a disturbing force. The result of the first mode of consideration will be, that the moon will describe an ellipse, whose line of apses does not move. The result of the second mode of consideration will be, that the instantaneous ellipse (in which the moon would proceed to move, if the additional force should cease) will have its line of apses regressing, while the moon is near perigee, and progressing while she is near apogee. There is however no incongruity between the immobility of the line of apses in the first mode of consideration, and the progress or regress in the second; because the line of apses of the instantaneous ellipse in the second case is an imaginary line, determined by supposing the disturbing force to cease, and the moon to move undisturbed. At the apses however the line of apses must be the same in both methods of consideration; since, whether the disturbing force cease or not, the perpendicularity of the direction of the motion to the radius vector determines the place of an apse. Consequently, while the moon moves from one apse to the other, the motions of the line of apses in the second mode of consideration must be such as to produce the same effect on the position of the line of apses as in the first mode of consideration; that is, they must not have altered its place; and hence the progression at one time must be exactly equal to the regression at the other time.

[†] Suppose, for facility of conception, that the force perpendicular to the radius vector acts in only one place in each quadrant between syzygies and quadratures. The portions of the orbit which are bisected by the line of syzygies will be described with greater velocity in consequence of this disturbance (abstracting all other causes), than the other portions. Now the curvature of any part of an orbit does not depend on the central force simply, or on the velocity, but on the relation between them; so that the same curve may be described either by leaving the central force unaltered and increasing the velocity in a given proportion, or by diminishing the central force in a corresponding proportion, and leaving the velocity unaltered. Consequently, in the case before us, the same curve will be described as if, without alteration of velocity, the central force were diminished, while the moon passed through the portions bisected by the line of syzygies. If now the imaginary diminution of central force were in the same proportion (that is, if the real increase of velocity were in the same proportion) at both syzygies, which here coincide with the apses, the regression of the line of apses produced at perigee would be equal to the progression produced at apogee. But the increase of velocity produced by the force perpendicular to the radius vector near apogee is much greater than that near perigee. First, because the force is greater in proportion to the distance. Second, because the time of describing a given small angle is greater in proportion to the square of the distance; so that the acceleration produced while the moon passes through a given angle is proportional to the cube of the distance. Third, because the velocity, which is increased by this acceleration, is inversely proportional to the distance; so that the ratio in which the velocity is increased is proportional to the fourth power of the distance. The effect at the greater distance therefore predominates over that at the smaller distance; and therefore, on the whole, the force perpendicular to the radius vector produces an effect similar to its apogeal effect; that is, it causes the line of apses to progress.

greater than the first consideration would lead us to think, for the following reasons :—

(106.) Firstly. The earth is revolving round the sun, or the sun appears to move round the earth, in the same direction in which the moon is going. This lengthens the time for which the sun acts in any one manner upon the moon, but it lengthens it more for the time in which the moon is moving slowly, than for that in which it is moving quickly. Thus, suppose that the moon's angular motion when she is near perigee is fourteen times the sun's angular motion ; and when near apogee, only ten times the sun's motion. Then she passes the sun at the former time (as seen from the earth), with $\frac{13}{14}$ths of her whole motion, but at the latter with only $\frac{9}{10}$ths ; consequently, when near perigee, the time in which the moon passes through a given angle from the moving line of syzygies (or the time in which the angle between the sun and moon increases by a given quantity), is $\frac{14}{13}$ths of the time in which it would have passed through the same angle, had the sun been stationary ; when near apogee, the number expressing the proportion is $\frac{10}{9}$ths. The latter number is greater than the former ; and, therefore, the effect of the forces acting near apogee is increased in a greater proportion than that of the forces acting near perigee. And as the effective motion of the line of apses is produced by the excess of the apogeal effect above the perigeal effect, a very small addition to the former will bear a considerable proportion to the effective motion previously found ; and thus the effective motion will be sensibly increased.

(107.) Secondly. When the line of apses is directed toward the sun, the whole effect of the force is to make it progress,—that is, to move in the same direction as the sun : the sun passes through about 27° in one revolution of the moon, and therefore departs only 16° from the line of apses ; and therefore the apse continues a long time near the sun. When at right angles to the line joining the earth and sun, the whole effect of the force is to make it regress ; and, therefore, moving in the direction opposite to the sun's motion, the angle between the sun and the line of apses is increased by 36° in each revolution, and the line of apses soon escapes from this position. The effect of the former force is therefore increased, while that of the latter is diminished ; and the preponderance of the former is much increased. It is in increasing the rapidity of progress at one time, and the rapidity of regress at another, that the force perpendicular to the radius vector indirectly increases the effect of the former in the manner just described.

(108.) From the combined effect of these two causes, the actual progression of the line of apses is nearly double of what it would have been if, in different revolutions of the moon, different parts of its orbit had been equally subjected to the disturbing force of the sun.

(109.) The line of apses, upon the whole, therefore, progresses ; and (as calculation and observation agree in showing) with an angular velocity that makes it (on the average) describe 3° in each revolution of the moon, and that carries it completely round in nearly nine years. But as it sometimes progresses and sometimes regresses for several months together, its motion its extremely irregular. The general motion of the line of apses has been known from the earliest ages of astronomy.

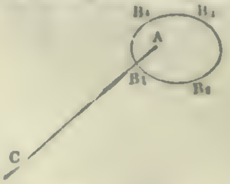
(110.) V. For the alteration of the excentricity of the moon's orbit : first, let us consider the orbit in the position in which the line of apses passes through the sun, *fig.* 31. While the moon moves from B_1 (the perigee) to B_3 (the apogee), the force in the direction of the radius vector is sometimes directed to the earth, and sometimes from the earth ; and, therefore, by (57) and (59), it sometimes diminishes the excentricity and sometimes increases it. But while the moon moves from B_3 to B_1, there are exactly equal forces acting in the same manner at corresponding parts of the half-orbit, and these, by (58), will produce effects exactly opposite. On the whole, therefore, the disturbing force in the direction of the radius vector produces no effect on the excentricity. The force perpendicular to the radius vector increases the moon's velocity when moving from B_4 to B_1, and diminishes it when moving from B_1 to B_2; in moving, therefore, from B_4 to B_1, the excentricity is increased (65) ; and in moving from B_1 to B_2, it is as much diminished (66). Similarly, in moving from B_2 to B_3, the excentricity is diminished ; and in moving from B_3 to B_4, it is as much increased. This force, therefore, produces no effect on the excentricity.

On the whole, therefore, while the line of apses passes through the sun, the disturbing forces produce no effect on the excentricity of the moon's orbit.

(111.) When the line of apses is perpendicular to the line joining the earth and sun, the same thing is true. Though the forces near perigee and near apogee are not now the same as in the last case, their effects on different sides of perigee and apogee balance each other in the same way.

(112.) But if the line of apses is inclined to the line joining the earth and sun, as in *fig.* 32, the effects of the forces do not balance. While the moon is near B_4 and near B_2 the disturbing force in the radius vector is directed to the earth ; at B_4 therefore, (58), as the moon is moving towards perigee, the excentricity is increased ; and at B_2, as the moon is moving from perigee, the excentricity is diminished. From the slowness of the motion at B_2 (which gives the disturbing force more time to produce its effects), and the greatness of the force, the effect at B_2 will preponderate, and the combined effects at B_2 and B_4 will diminish the excentricity. This will appear from reasoning of the same kind as that in (98). At B_1 and B_3 the force in the radius vector is directed from the earth : at B_1, therefore, by (59), as the moon is moving from perigee, the excentricity is increased, and at B_3 it is diminished ; but from the slowness of the motion at B_3 and the magnitude of the force, the effect at B_3 will preponderate, and the combined effects at B_1 and B_3 will diminish the excentricity. On the whole, therefore, the force in the direction of the radius vector diminishes the excentricity. The force perpendicular to the radius vector retards the moon from B_1 to B_2, but the first part of this motion may be considered near perigee, and the second near apogee, and, therefore, in the first part, it diminishes the excentricity, and in the second increases it ; and the whole effect from B_1 to B_2 is very small. Similarly, the whole effect from B_3 to B_4 is very small. But from B_4 to B_1 the force accelerates the moon, and, therefore, by (68), (the moon being near perigee) increases the excentricity ; and from B_2 to B_3 the force also accelerates the moon, and by (68) (the moon being near apogee) diminishes the excentricity ; and the effect is much * greater (from the slowness of the moon and the greatness of the force) between B_2 and B_3, than between B_4 and B_1, and therefore the combined effect of the forces in these two quadrants is to diminish the excentricity.

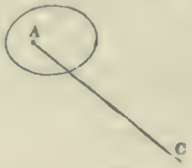
Fig. 32.



On the whole, therefore, when the line of apses is inclined to the line joining the earth and sun, in such manner that the moon passes the line of apses before passing the line joining the earth and sun, the excentricity is diminished at every revolution of the moon.

(113.) In the same manner it will appear that if the line of apses is so inclined that the moon passes the line of apses after passing the line joining the earth and sun, the excentricity is increased at every revolution of the moon. Here the force in the radius vector is directed to the earth, as the moon moves from perigee and from apogee ; and is directed from the earth as the moon moves to perigee and to apogee ; which directions are just opposite to those in the case already considered. Also the force perpendicular to the radius vector retards the moon both near perigee and near apogee ; and this is opposite to the direction in the case already considered. On the whole, therefore, the excentricity is increased at every revolution of the moon.

Fig. 33.



(114.) In every one of these cases the effect is exactly the same if the sun be supposed on the side of the moon's orbit, opposite to that represented in the figure.

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* To the reader who is acquainted with Newton's 3rd section, the following demonstration of this point will be sufficient : Four times the reciprocal of the *latus rectum* is equal to the sum of the reciprocals of the apogeal and perigeal distances. The effect of an increase of velocity at perigee in a given proportion is to alter the area described in a given time in the same proportion, and therefore to alter the *latus rectum* in a corresponding proportion. Consequently an increase of velocity at perigee in a given proportion alters the reciprocal of the apogeal distance by a given quantity, and therefore alters the apogeal distance by a quantity nearly proportional to the square of the apogeal distance ; and therefore the ratio of the alteration of apogeal distance to apogeal distance (on which the alteration of excentricity depends) is nearly proportional to the apogeal distance. Similarly, if the velocity at apogee is increased in a given proportion, the ratio of the alteration of perigeal distance to perigeal distance (on which the alteration of excentricity depends) is nearly proportional to the perigeal distance. Thus if the velocity were increased in the same proportion at perigee and at apogee, the increase of excentricity at the former would be greater than the diminution at the latter, in the proportion of apogeal distance to perigeal distance. But in the case before us, the proportion of increase of velocity is much greater at apogee than at perigee. First, because the force is greater (being in the same proportion as the distance). Second, because the time in which the moon describes a given angle is greater (being in the same proportion as the square of the distance), so that the increase of velocity is in the proportion of the cube of the distance. Third, because the actual velocity is less (being inversely as the distance), so that the ratio of the increase to the actual velocity is proportional to the fourth power of the distance. Combining this proportion with that above, the alterations of excentricity in the case before us, produced by the forces acting at apogee and at perigee, are in the proportion of the cubes of the apogeal and perigeal distances respectively.

(115.) Now the earth moves round the sun, and the sun therefore appears to move round the earth, in the order successively represented by the *figs.* 31, 32, and 33. Hence; then; when the sun is in the line of the moon's apses, the excentricity does not alter (110); after this it diminishes till the sun is seen at right angles to the line of apses (112); then it does not alter (111); and after this it increases till the sun reaches the line of apses on the other side. Consequently, the excentricity is greatest when the line of apses passes through the sun, and is least when the line of apses is perpendicular to the line joining the earth and sun.

The amount of this alteration in the excentricity of the moon's orbit is more than $\frac{1}{5}$th of the mean value of the excentricity; the excentricity being sometimes increased by this part, and sometimes as much diminished; so that the greatest and least excentricities are nearly in the proportion of 6 : 4 or 3 : 2.

(116.) The principal inequalities in the moon's motion may therefore be stated thus:

1st. The *elliptic inequality*, or *equation of the centre* (31), which would exist if it were not disturbed.
2nd. The *annual equation* (90), depending on the position of the earth in the earth's orbit.
3rd. The *variation* (93), and *parallactic inequality* (94), depending on the position of the moon with respect to the sun.
4th. The general *progression of the moon's perigee* (104).
5th. The *irregularity in the motion of the perigee*, depending on the position of the perigee with respect to the sun (109).
6th. The *alternate increase and diminution of the excentricity*, depending on the position of the perigee with respect to the sun (115).

These inequalities were first explained (some imperfectly) by Newton, about 1680.

(117.) The effects of the two last are combined into one called the *evection*. This is by far the largest of the inequalities affecting the moon's place: the moon's longitude is sometimes increased 1° 15′ and sometimes diminished as much by this inequality. It was discovered by Ptolemy, from observation, about A.D. 140.

(118.) It will easily be imagined that we have here taken only the principal inequalities. There are many others, arising chiefly from small errors in the suppositions that we have made. Some of these, it may easily be seen, will arise from variations of force which we have already explained. Thus the difference of disturbing forces at conjunction and at opposition, whose principal effect was discussed in (94), will also produce a sensible inequality in the rate of progression of the line of apses, and in the dimensions of the moon's orbit. The alteration of disturbing force depending on the excentricity of the earth's orbit will cause an alteration in the magnitude of the *variation* and the *evection*. The alteration of that part mentioned in (94) produces a sensible effect depending on the angle made by the moon's radius vector with the earth's line of apses. All these, however, are very small: yet not so small but that, for astronomical purposes, it is necessary to take account of thirty or forty.

(119.) There is, however, one inequality of great historical interest, affecting the moon's motion, of which we may be able to give the reader a general idea. We have stated in (89) that the effect of the disturbing force is, upon the whole, to diminish the moon's gravity to the earth: and in (90) we have mentioned that this effect is greater when the earth is near perihelion, than when the earth is near aphelion. It is found, upon accurate investigation, that half the sum of the effects at perihelion and at aphelion is greater than the effect at mean distance, by a small quantity depending on the excentricity of the earth's orbit: and, consequently, the greater the excentricity (the mean distance being unaltered) the greater is the effect of the sun's disturbing force. Now, in the lapse of ages, the earth's mean distance is not sensible altered by the disturbances which the planets produce in its motion; but the excentricity of the earth's orbit is sensibly diminished, and has been diminishing for thousands of years. Consequently the effect of the sun in disturbing the moon has been gradually diminishing, and the gravity to the earth has therefore, on the whole, been gradually increasing. The size of the moon's orbit has therefore, gradually, but insensibly, diminished (47): but the moon's place in its orbit has sensibly altered (49), and the moon's angular motion has appeared to be perpetually quickened. This phenomen was known to astronomers by the name of the *acceleration of the moon's mean motion*, before it was theoretically explained in 1787, by Laplace: on taking it into account, the oldest and the newest observations are equally well represented by theory. The rate of progress of the moon's line of apses has, from the same cause, been somewhat diminished.

SECTION VI.—*Theory of Jupiter's Satellites.*

(120.) Jupiter has four satellites revolving round him in the same manner in which the moon revolves round the earth; and it might seem, therefore, that the theory of the irregularities in the motion of these satellites is similar to the theory of the irregularities in the moon's motion. But the fact is, that they are entirely different. The fourth satellite (or that revolving in the largest orbit) has a small irregularity analogous to the moon's variation, a small one similar to the evection, and one similar to the annual equation: but the last of these amounts only to about two minutes, and the other two are very much less. The corresponding inequalities in the motion of the other satellites are still smaller. But these satellites disturb each other's motions, to an amount and in a manner of which there is no other example in the solar system; and (as we shall afterwards mention) their motions are affected in a most remarkable degree by the shape of Jupiter.

(121.) The theory, however, of these satellites is much simplified by the following circumstances:—First, the disturbances produced by the sun may, except for the most accurate computations, be wholly neglected. Secondly, that the orbits of the two inner satellites have no excentricity independent of perturbation. Thirdly, that a very remarkable relation exists (and, as we shall show, necessarily exists) between the motions of the three first satellites.

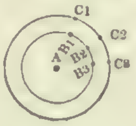
Before proceeding with the theory of the first three satellites, we shall consider a general proposition which applies to each of them.

(122.) Suppose that two small satellites revolve round the same planet; and that the periodic time of the second is a very little greater than double the periodic time of the first; what is the form of the orbit in which each can revolve, describing a curve of the same form at every revolution?

(123.) The orbits will be sensibly elliptical, as the perturbation produced by a small satellite in one revolution will not sensibly alter the form of the orbit. The same form being supposed to be described each time, the major axis and the excentricity are supposed invariable, and the position of the line of apses only is assumed to be variable. The question then becomes, What is the excentricity of each orbit, and what the variation of the position of the line of apses, in order that a curve of the same kind may be described at every revolution?

(124.) In *fig.* 34, let B_3, B_1, B_2, represent the orbit of the first, and C_3, C_1, C_2, the orbit of the second. Suppose that when B was at B_1, C was at C_1, so that A, B_1, C_1, were in the same straight line, or that B and C were in conjunction at these points. If the periodic time of C were exactly double of the periodic time of B, B would have made exactly two revolutions, while C made exactly one; and, therefore, B and C would again be in conjunction at B_1, and C_1. But as the periodic time of C is a little longer than double that of B, or the angular motion of C rather slower than is supposed, B will have come up to it (in respect of longitude as seen from A) at some line B_2 C_2, which it reaches *before* reaching the former line of conjunction B C_1. And it is plain that there has been no other conjunction since that with which we started as the successive conjunctions can take place only when one satellite has gained a whole revolution on the other. The first conjunction then being in the line A B_1 C_1, the next will be in the line A B_2 C_2, the next in a line A B_3 C_3, still farther from the first, &c.; so that the line of conjunction will regress slowly; and the more nearly the periodic time of one satellite is double that of the other, the more slowly will the line of conjunction regress.

Fig. 34.



(125.) As the principal part of the perturbation is produced when the satellites are near conjunction (in consequence of the smallness of their distance at that time), it is sufficiently clear that the position of the line of apses, as influenced by the perturbation, must depend on the position of the line of conjunction; and, therefore, that the motion of the line of apses must be the same as the motion of the line of conjunction. Our question now becomes this: What must be the excentricities of the orbits, and what the positions of the perijoves, in order that the motions of the lines of apses, produced by the perturbation, may be the same as the motion of the line of conjunction?

(126.) If the line of apses of the first satellite does not coincide with the line of conjunction, the first satellite at the time of conjunction will either be moving from perijove towards apojove, or from apojove towards perijove. If the former, the disturbing force, which is directed from the central body, will, by (59), cause the excentricity to increase; if the latter, it will cause it to decrease. As we have started with the supposition, that the excentricity is to be supposed invariable, neither of these consequences can be allowed, and, therefore, the line of apses must coincide with the line of conjunction.

(127.) If the apojove of the first satellite were in the direction of the points of conjunction, the disturbing force in the direction of the radius vector, being directed from the central body, would, by (54), cause the line of apses to progress. Also the force perpendicular to the radius vector, before the first satellite has reached conjunction (and when the second satellite, which moves more slowly, is nearer to the point of conjunction than the first), tends to accelerate the first satellite; and that which acts after the satellites have passed conjunction, tends to retard the first satellite; and both these, by (65) and (66), cause the line of apses to progress. But we have assumed, that the line of apses shall move in the same direction as the line of conjunction, that is, shall regress; therefore, the apojove of the first satellite cannot be in the direction of the points of conjunction.

(128.) But if we suppose the perijove of the first satellite to be in the direction of the points of conjunction, every thing becomes consistent. The disturbing force, in the direction of the radius vector, from the central body, will, by (51), cause the line of apses to regress. The force perpendicular to the radius vector, which accelerates the first satellite before it has reached conjunction, that is, before it has reached the perijove, and retards it after that time, will also, by (65) and (66), cause the line of apses to regress. Also, as in (56), this regression will be greater as the excentricity of the orbit is less, because the disturbing force, which acts here, does not depend on the excentricity. By proper choice, therefore, of a value of the excentricity, we can make an orbit, whose line of apses will always regress exactly as fast as the line of conjunction, and will, therefore, always coincide with it; whose excentricity, in consequence, will never alter, by (59) and (68); and whose general shape, therefore, will be the same at every successive revolution.

(129.) We shall mention hereafter, that the form of Jupiter is such as would cause the perijove of the first satellite, if it were not disturbed by the second satellite, to progress with a velocity not depending upon the excentricity of the orbit. The only alteration which this makes in our conclusions is, that the excentricity of the orbit must be so chosen, that the perturbation of which we have spoken will cause a regression equal to the *sum* of the progression which Jupiter's shape would occasion, and the regression of the line of conjunction. As this is greater than the regression of the line of conjunction alone, the excentricity of the orbit must be less. So that the only effect of Jupiter's shape is to diminish, in some degree, the excentricity of the orbit.

(130.) Now let us inquire what must be the form and position of the orbit of the second satellite. As before, the principal part of the perturbation is near conjunction. At and near the conjunction, the disturbing force, in the direction of the radius vector, is directed to the central body. Before conjunction, when the first satellite is less advanced than the second, the disturbing force, perpendicular to the radius vector, retards the second, by (86). For, the periodic time of the second being nearly double that of the first, the mean distances from the planet will be nearly in the proportion of 7 to 11 (as the proportion of the cube of 7 to the cube of 11 is nearly the same as the proportion of the square of 1 to the square of 2, see (34)), and, therefore, near conjunction, the distance of the first from the second is less than the distance of the first from the central body. After conjunction, the disturbing force accelerates the second body. Now, without going through several cases as before, which the reader will find no trouble in doing for himself, we shall remark, at once, that if the apojove of the second satellite is in the direction of the points of conjunction, both the disturbing force, directed to the central body at apojove, and that perpendicular to the radius vector, retarding it before it reaches apojove, and accelerating it afterwards, by (53), (65), and (66), will cause the line of apses to regress; and that, by proper choice of excentricity, the regression of the line of apses may be made exactly equal to the regression of the line of conjunction.

(131.) Our conclusion, therefore, is: If two satellites revolve round a primary, and if the periodic time of one is very little greater than double the periodic time of the other, and if we assume that the orbits described have always the same form; (that is, if they have no excentricity independent of perturbation); then the orbits will not sensibly differ from ellipses, the lines of apses of both orbits must always coincide with the line of conjunctions, and the perijove of the first orbit, and the apojove of the second, must always be turned towards the points of conjunction. It appears also, that these conditions are sufficient, inasmuch as the rate of regress of the lines of apses will (with proper values for the excentricities) be the same as the rate of regress of the line of conjunctions, and the excentricities then will not change. The excentricities of the orbits will be greater as the regress of the line of conjunctions is slower, or as the proportion of the periodic times approaches more exactly to the proportion of 1 : 2.

(132.) In the same manner it would be found, that if the periodic time of one satellite were very little less than double that of the other, the lines of apses (in order that similar orbits may be traced out at each revolution) must always coincide with the line of conjunction, and the apojove of the first satellite and the perijove of the second must always be turned towards the points of conjunction; and the excentricities of the orbits must be greater, as the proportion of the periodic times approaches more exactly to the proportion of 1 : 2.

(133.) The same thing exactly would hold, if the periodic times were very nearly in the ratio of 2 : 3, or of 3 : 4, &c., but these suppositions do not apply to Jupiter's satellites.

(134.) Having thus found the distortion produced by the disturbing force in orbits which have no excentricity independent of perturbation, it will easily be imagined that the same kind of distortion will be produced if the orbits have an original excentricitiy. If we make in an elliptic orbit, the same kind of alteration which must be made in a circular orbit, in order to form the figure found above, we shall have nearly the orbit that will be described from the combined effects of perturbation and of excentricity independent of perturbation.*

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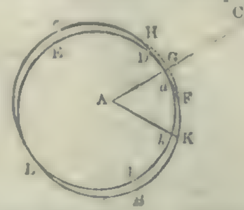
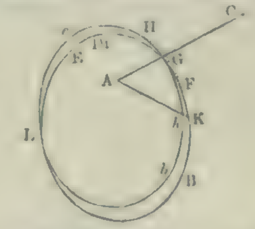
* The truth of this proposition may be shown more fully in the following manner: Let A (*fig.* 35) be the place of the primary, AC the line of conjunctions of the first and second satellite, BDE the elliptic orbit, in which the first satellite would move if undisturbed, D its perijove. Suppose (to simplify the figure) that the attraction of the second satellite acts only for a limited space; for instance, while the first satellite passes from F to H. Then the result of the investigations from (122) to (131) is, that the first satellite will be drawn

Fig. 35.



outwards from the orbit in which it would have moved, so as to describe a curve FGH; and when the disturbing force ceases at H, it will proceed to describe an ellipse, H*ebd*, similar to BDE, but with this difference, that the perijove is at *d* instead of D. The conclusion, however, now that it has been securely obtained from the reasoning above, may be stated as the result of the following reasoning: In consequence of the disturbing force, which has drawn the first satellite outwards, without, upon the whole, altering its velocity accelerating it before conjunction, and retarding it afterwards, the satellite has moved in a curve, FGH, external to the ellipse FD, in which it would have moved; and after the disturbing force has ceased at H, the satellite (which is moving in a path inclined externally from the old orbit) continues to recede from the old orbit till the diminution of velocity (26) allows its path to be so much curved, that at *e* it begins to approach, and at L the new orbit intersects the old one; and after this, the path is inclined internally from the old orbit, till the increase of velocity (25) makes its path so little curved that it approaches the old orbit again, and again crosses it between *d* and D. In like manner, if, as in *fig.* 36, the orbit BFE have an excentricity independent of perturbation (the perijove being at any point D_1), nevertheless, we may state that, in consequence of the disturbing force, the satellite will move in a curve FGH external to FE; but when the disturbing force ceases at H, the satellite (which is moving in a path

Fig. 36.



inclined externally from the old orbit) continues to recede from the old orbit till the diminution of velocity (26) allows its path to be so much curved, that it begins to approach at some point *e*; that at some point L, nearly opposite to C, the new orbit intersects the old one; and that, after this, the path is inclined internally from the old orbit, till the increase of velocity (25) makes its path so little curved that it approaches the old orbit again, and again crosses it between F and H. Thus, the alteration of the radius vector, drawn in any given direction, as AK (which in the new orbit is altered to A*k*) is nearly the same in the second case as in the first. This, however, is the alteration produced in a single revolution of the satellite; but as the same applies to every successive revolution, it follows that the inequality or variation of the radius vector in the second case is nearly the same as in the first case; and thus the proposition of the text is proved.

The inequality of the radius vector would be somewhat different if the excentricity of the orbit in the second case were considerable, partly because the places of conjunction would not be at equal angular distances, partly because the disturbing forces would be different (as the distance between the satellites in conjunction would not always be the same), and partly because the effect of a given force is really different, according to the part of the orbit at which it acts. But where the excentricity is so small, as in the orbit of Jupiter's third satellite, or in those of the old planets, the alteration of the inequality of the radius vector produced by these differences is hardly sensible.

The reasoning of this note may be applied, with the proper alterations, to every case of perturbation, produced by a disturbing force which is nearly independent of the form of the orbit; and as this will apply successively to each of the causes producing disturbance, we shall at last arrive at the following general proposition: If several disturbing forces act on a planet or satellite, and if we estimate the inequality in the radius vector, which each of these would produce, supposing the orbit to have no excentricity independent of perturbation; then the inequality really produced, supposing the orbit to have an independent excentricity, will be nearly the same as the sum of all the inequalities so estimated.

It is to be remarked, that if an orbit have an independent excentricity, and if the orbit receive an alteration similar to an elliptic inequality (that is, if it be elongated on one side and flattened on the other), the orbit is still sensibly an ellipse, of which the original focus is still the focus. Thus, in the instance occupying the first part of this note, as the inequality impressed on the elliptic orbit in the second case is the same as the inequality in the first case, that is, is similar to an elliptic inequality, the orbit so altered will still be an ellipse, whose excentricity and line of apses are altered. We might, therefore, have obtained our results by at once investigating the alterations of the excentricity and line of apses produced by the disturbing forces; but the method adopted in the text is simpler.

We shall now proceed with the application of these conclusions to Jupiter's first three satellites.

(135.) The periodic time of Jupiter's first satellite is, 1 day, 18 hours, 27 minutes, and 34 seconds; that of the second satellite is, 3 days, 13 hours, 13 minutes, and 42 seconds; that of the third satellite is, 7 days, 3 hours, 42 minutes, and 32 seconds. The periodic time of the second satellite exceeds, by a small quantity, double that of the first, so that the preceding investigations apply to the motion of these two satellites. In fact, 275 revolutions of the first satellite are finished in almost exactly the same time as 137 revolutions of the second. If then, at a certain time, these two satellites start from conjunction, they will be in conjunction near the same place at every revolution of the second satellite, or at every second revolution of the first satellite: but the line of conjunction will regress slowly; and when the first satellite has finished 275 revolutions, or one revolution more than double the number made by the second satellite, they will again be in conjunction in the same place as before, the line of conjunction having regressed till it has again reached the same position; this takes place in 486½ days.

(136.) From the preceding investigation then it appears that, as these orbits have no excentricity independent of perturbation, they will be elliptic, and the line of apses of each orbit will regress so as to turn completely round in 486½ days; and that when in conjunction, the first satellite will always be in perijove, and the second satellite will always be in apojove.

(137.) But the periodic time of the third satellite is almost exactly double that of the second satellite, exceeding the double by a small quantity; and on this account the orbit of the second satellite will be distorted from the form which otherwise it would have had, by an inequality similar to that just investigated. In a word, the line of conjunction of the second and third satellites will slowly regress, and the orbit of the second satellite will always be compressed on the side next the points of conjunction, and elongated on the opposite side; and the orbit of the third satellite will always be elongated on the side next the points of conjunction, and compressed on the opposite side.

(138.) Now we come to the most extraordinary part of this theory. We have remarked that 275 revolutions of the first satellite are finished in almost exactly the same time as 137 revolutions of the second; but it will also be found that 137 revolutions of the second are finished in almost exactly the same time as 68 revolutions of the third: all these revolutions occupying 486½ days. Because 275 exceeds the double of 137 by 1, we have inferred that the line of conjunctions of the first and second satellites regresses completely round in 275 revolutions of the first satellite, or in 486½ days. In like manner, because 137 exceeds the double of 68 by 1, we infer that the line of conjunctions of the second and third satellites regresses completely round in 137 revolutions of the second satellite, or in 486½ days. Hence we have this remarkable fact: *the regression of the line of conjunction of the second and third satellites is exactly as rapid as the regression of the line of conjunction of the first and second satellites.* So accurate is this law, that in the thousands of revolutions of the satellites, which have taken place since they were discovered, not the smallest deviation from it (except what depends upon the elliptic form of the orbit of the third satellite) has ever been discovered.

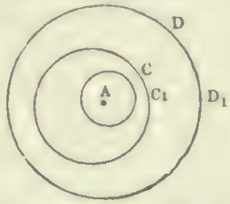
(139.) Singular as this may appear, the following law is not less so. *The line of conjunction of the second and third satellites always coincides with the line of conjunction of the first and second satellites produced backwards, the conjunctions of the second and third satellites always taking place on the side opposite to that on which the conjunctions of the first and second take place.* This defines the relative position of the lines of conjunction, which (by the law of last article) is invariable. Like that law it has been found, as far as observation goes, to be accurately true in every revolution since the satellites were discovered.

(140.) The most striking effect of these laws in the perturbations of the satellites is found in the motions of the second satellite. In consequence of the disturbing force of the first satellite, the orbit of the second satellite will be elongated towards the points of conjunction of the first and second (130), and consequently compressed on the opposite side. In consequence of the disturbing force of the third satellite, the orbit of the second satellite will be compressed on the side next the points of conjunction of the second and third (128). And because the points of conjunction of the second and third are always opposite to the points of conjunction of the first and second, the place of compression from one cause will always coincide with the place of compression from the other cause; and therefore the orbit of the second satellite will be very much compressed on that side, and consequently very much elongated on the other side. The excentricity of the orbit, depending thus entirely on perturbation, exceeds considerably the excentricity of the orbit of Venus. The inequalities in the motions of the satellites, produced by these excentricities, were first discovered (from observation) by Bradley about A.D. 1740, and first explained from theory by Lagrange, in 1766.

(141.) The singularity of these laws, and the accuracy with which they are followed, lead us to suppose that they do not depend entirely on chance. It seems natural to inquire, whether some reason may not be found in the mutual disturbance of the satellites, for the preservation of such simple relations. Now we are able to show that, supposing the satellites put in motion at any one time, nearly in conformity with these laws, their mutual attraction would always tend to make their motions follow these laws exactly. We shall show this by supposing a small departure from the law, and investigating the nature of the forces which will follow as a consequence of that departure.

(142.) Suppose, for instance, that the third satellite lags behind the place defined by this law; that is, suppose that when the second satellite is at the most compressed part of its ellipse, (as produced by the action of the first satellite,) the third satellite is behind that place. The conjunction then of the second and third satellites will happen before reaching the line of apses of the orbit of the second, as produced by the action of the first. Now in the following estimation of the forces which act on the third satellite, and of their variation depending on the variation of the positions of the lines of conjunction, there is no need to consider the influence which the ellipticity of the orbit of the second as produced by the third, or that of the third as produced by the second, exerts upon the third satellite; because the flattening arising from the action of the third, and the elongation arising from the action of the second, will always be turned towards the place of conjunction of the second and third, and the modification of the action produced by this flattening and elongation will always be the same, whether the lines of conjunction coincide or not. In *fig.* 37, let C be the perijove of the orbit of the second satellite, (as produced by the action of the 1st satellite alone,) D the point of the orbit of the third, which is in the line A C produced. If the third satellite is at D when the second is at C, the force produced by the second perpendicular to the radius vector, retards the third before it reaches D, and accelerates it after it has passed D, by equal quantities. But if, as in the supposition which we have made, the conjunction takes place in the line $A\ C_1\ D_1$, the retardation of the third satellite before conjunction is produced by the attraction of the second satellite before it arrives at perijove, when it is near to the orbit of the third satellite, (and therefore acts powerfully,) and moves slowly, (and therefore acts for a long time); while the acceleration after conjunction is produced by the second satellite near its perijove, when it is far from the orbit of the third satellite, (and therefore acts weakly,) and moves rapidly (and therefore acts for a short time). The retardation therefore exceeds the acceleration; and the consequence is, by (48), that the periodic time of the third satellite is shortened, and therefore its angular motion is quickened; and therefore, at the next conjunction, it will have gone further forward before the second satellite can come up with it, or the line of conjunction will be nearer to the place of perijove of the second satellite, depending on the action of the first. In the same manner, if we supposed the third satellite moving rather quicker than it ought in conformity with the law, the tendency of the forces would be to accelerate it, to make its periodic time longer, and thus to make its angular motion slower. By the same kind of reasoning it will be seen that there are forces acting on the first satellite, produced by the elliptic inequality which the third impresses on the orbit of the second, tending to accelerate the angular motion of the first satellite in the first case, and to retard it in the second. The same reasoning will also show that both the first and third satellites exert forces on the second, tending to retard its angular motion in the first case, and to accelerate it in the second. All these actions tend to preserve the law: in the first case by making the line of conjunctions of the first and second satellite regress, and that of the second and third progress, till they coincide; and in the second case, by altering them in the opposite way, till they coincide.

Fig. 37.



(143.) Perhaps there is no theoretical permanence of elements on which we can depend with so great certainty, as on the continuance of this law. The greatest and most irregular perturbations of Jupiter or of his satellites, provided they come on gradually, will not alter the relation between their motions; the effect of a resisting medium will not alter it; though each of these causes would alter the motions of all the satellites; and though similar causes would wholly destroy the conclusions which mathematicians have drawn as to the stability of the solar system, with regard to the elements of the planetary orbits. The physical explanation of this law was first given by Laplace, in A.D. 1784.

(144.) We have terminated now the most remarkable part of the theory of these satellites. There are however some other points which are worth attending to, partly for their own sake, and partly as an introduction to the theory of the planets.

(145.) The orbit of the third satellite, as we have mentioned, has a small excentricity independent of perturbation. Consequently, when the conjunction with the second takes place near the independent perijove of the third, the effect of the disturbance on the second is rather greater than at any other time; and this produces an irregularity in the excentricity of the second, and in the motion of its apses, depending on the distance of the line of conjunction from the independent perijove of the third. The departure from uniformity in the angular motion of the third also produces a departure from uniformity in the regression of the line of conjunction, and this contributes to the same irregularity.

(146.) The disturbing force in the direction of the radius vector, produced by an inner satellite, is sometimes directed to the central body and sometimes from it; but on the whole the former exceeds the latter (80). Now the principal part of the effect really takes place when the satellites are near conjunction; consequently, when the line of conjunction passes near the independent perijove of the third satellite, the force by which the third satellite is urged to the planet is greater than at any other time; and as the line of conjunction revolves, the force alternately increases and diminishes. This produces an irregularity in the major axis, and consequently in the motion of the third satellite (47), depending on the distance of the line of conjunction from the perijove of the third.

(147.) The disturbing force in the direction of the radius vector produced by an outer satellite is sometimes directed to the central body and sometimes from it; but on the whole the latter exceeds the former (80). For the reasons therefore, in the last article, there is in the motion of the second satellite an irregularity depending on the distance of the line of conjunction from the independent perijove of the third, but opposite in its nature to that of the third satellite.

(148.) Each of these irregularities in the motion of one of these satellites produces an irregularity in the motion of the others; and thus the whole theory becomes very complicated when we attempt to take the minute irregularities into account.

(149.) The motion of the fourth satellite is not related to the others in the same way in which they are related among themselves. Its periodic time is to the periodic time of the third nearly in the proportion of 7 : 3. Some of the irregularities then which it experiences and which it occasions are nearly similar to those in the motions of the planets. These however are small: the most important are those depending on the changes in the elements which require many revolutions of the satellites to go through all their various states, but which nevertheless have been observed since the satellites were discovered. We shall proceed with these.

(150.) First, let us suppose that the third satellite has no excentricity independent of perturbation, and that the fourth satellite has a sensible excentricity, its line of apses progressing very slowly, in consequence principally of the shape of Jupiter (so slowly as not to have gone completely round in eleven thousand revolutions of the satellite). When each of the satellites has revolved a few hundred times round Jupiter, their conjunctions will have taken place almost indifferently in every part of their orbits. If the orbit of the fourth as well as that of the third had no independent ellipticity, there would be no remarkable change of shape produced by perturbation, as the action of one satellite upon the other would be the same when in conjunction in all the different parts of the orbit. But the orbit of the fourth being excentric, the action of each satellite on the other is greatest when the conjunction happens near the perijove of the fourth satellite. We may consider then that the preponderating force takes place at this part of the orbits; and we have to inquire what form the orbit of the third satellite must have, to preserve the same excentricity at every revolution. It must be remembered here that the effect of Jupiter's shape is to cause a more rapid progress of the line of apses of the third satellite, if its orbit be excentric, than of the line of apses of the fourth.

(151.) Considering then that the preponderating force on the third satellite in the direction of the radius vector is directed from the central body towards the perijove of the fourth, and that the preponderating force perpendicular to the radius vector accelerates it as it approaches that part, and retards it afterwards, it is plain from (51), (65), and (66), that if the perijove of the third satellite were in that position, the forces would cause the line of apses to regress; and this regression, if the excentricity of the third be small, may be considerable (though the preponderance of force which causes it is extremely small), and may overcome so much of the progression caused by Jupiter's shape, as to make the real motion of the line of apses as nearly equal as we please to the motion of the line of apses of the fourth. But the motion of the line of apses of the fourth will itself be affected (though very little) by the greater action of the third satellite on it at the same place; and the part in the radius vector being directed at its perijove to the central body, and the part perpendicular to the radius vector retarding it before it reaches the perijove, and accelerating it afterwards, will cause a small increase of progression of its apse. The state of things will be permanent, so far as depends on these forces, when the increased progression of the apse of the fourth satellite is equal to the diminished progression of the apse of the third; and thus the progression of the apse of the fourth will be somewhat increased, and the third satellite's orbit will have a compression corresponding in direction to the perijove of the fourth, and an elongation in the same direction as the apojove of the fourth. This would be the case if the third satellite had no excentricity independent of perturbation; but we may, as in other cases, consider that the same kind of distortion will be produced in the orbit if it has an independent excentricity.

(152.) Now let us suppose the fourth satellite to have no excentricity independent of perturbation, and the third satellite to have an independent excentricity. The greatest action will now be at the apojove of the third satellite, and this will (though in a small degree) cause the line of apses of the third satellite to progress; that is, it will increase the rapidity of progression which Jupiter's shape gives it. If now we wish to discover the form of orbit of the fourth satellite which will at every revolution preserve the same excentricity, and have its line of apses always corresponding with that of the third satellite, and therefore progressing more rapidly than the shape of Jupiter alone would make it progress, we must evidently suppose the perijove of the fourth satellite turned towards the apojove of the third, and, by supposing the excentricity small enough, the progression may be made as rapid as we please. Thus the effect of excentricity in the orbit of the third satellite is, that its line of apses is made to progress rather more rapidly, and that the orbit of the fourth satellite is compressed on the side next the apojove of the third satellite, and elongated on the opposite side. We have supposed for this investigation that the fourth satellite had no excentricity independent of perturbation, but the conclusion as to the distortion of the orbit may be applied if we suppose it to have independent excentricity.

(153.) In fact, the orbits of both the third and fourth satellites have independent excentricities, and both our conclusions apply to them. The fourth satellite, besides its independent excentricity, has an excentricity impressed upon it, opposite in kind to that of the third; and the third satellite, besides its independent excentricity, has an excentricity impressed upon it of the same kind as that of the fourth. In the same manner, the orbits of the first and second satellites have small excentricities impressed on them, similar in their kind to those of the third and fourth.

(154.) It will readily be conceived that the excentricities of the orbit of the third satellite will affect the great inequality (137) which it produces in the motion of the second; and on the contrary, that the inequality in the motion of the third produced by the attraction of the second, will influence the effect of the third on the fourth. We shall not however notice these further than to state that their effects are small.

(155.) We have now gone over the principal inequalities of the motions of Jupiter's satellites. They are so much connected, and (as we may say) so completely entangled, that though they may be explained in the way in which we have considered them, it would hardly be possible to calculate them in that way. A mathematical process of the most abstruse kind, which will at the same time embrace the motions of all, is alone competent to this object. We shall however have attained our end if we have given the reader a general idea of the explanation of disturbances in the most curious and complicated system that has ever been reduced to calculation.

SECTION VII.—*Theory of Planets.*

(156.) The theory of the planets may be considered as holding a middle place between that of our moon and that of Jupiter's satellites. In our moon, the principal inequalities are those that exhibit themselves in nearly the same order at every revolution, or, at longest, in the earth's revolution round the sun, depending entirely upon the relative position of the moon, the sun, and the lines of apses. In Jupiter's satellites, some of the principal inequalities (as those of the third and fourth satellites) do not depend at all upon the relative position of the bodies, but depend on the position of the lines of apses, whose revolutions, though slow, may yet be completely observed. But in the planets the terms analogous to those which we have mentioned in the moon's motions are small; the changes of elements are so slow, that though they may be in some degree observed, many thousands of years would be necessary to observe them completely. The most remarkable irregularities are those produced by changes in the elements occupying several revolutions of the planets, and more nearly analogous to the mutual perturbations of the three first satellites of Jupiter than to any other that we have seen; differing from them however in this respect, that for most of them independent excentricities are quite essential.

(157.) There are, however, some terms very nearly similar to those mentioned in the theory of the moon. Suppose, for instance, we consider the perturbations of Mercury by Jupiter (whose distance from the sun is more than thirteen times as great). This case is almost exactly analogous to the case of the moon disturbed by the sun. And in consequence, Mercury's orbit is flattened a little on the sides nearest to and farthest from Jupiter; but this effect is much disguised by the effect of forces analogous to those mentioned in (94), which here preponderates greatly: his line of apses progresses a little at every revolution, when Jupiter is nearly in that line, and regresses a little when Jupiter is in the line perpendicular to it: his orbit is a little more excentric in the former case, and a little less so in the latter; and his orbit is a little larger when Jupiter is at perihelion than when at aphelion. The same thing applies very nearly to the disturbances of Venus, the Earth, and Mars, produced by Jupiter.

(158.) The instance taken above is almost an extreme one. When we consider the perturbations of two planets which are nearer to each other, we are obliged to alter our conclusions considerably. The disturbing force becomes so much greater where the planets are near conjunction than at any other part, that the orbit is much more changed there than at any other part. However, the reasoning upon which, in (91), we determined the form of the moon's orbit, laying aside the consideration of independent excentricity, will, to a certain extent, apply here. The orbit in several cases will be flattened on the side where conjunction takes place, and on the opposite side, but generally most so on the latter; and will be made protuberant at the parts where the disturbing force tends wholly to increase the gravitation towards the sun. The same general reasoning will, in many cases, help us to find the form of the orbit which is influenced by the attraction of an interior planet.

(159.) A consideration, however, of particular cases will show how cautious we must be in applying this conclusion. Suppose, for instance, we consider the reciprocal perturbations of the Earth and Mars. The periodic time of Mars is nearly double that of the Earth. Here, then, we fall upon an inequality of the same kind as that discussed in (122), &c., for the satellites of Jupiter. And though the periodic time of Mars is not *very* nearly double that of the Earth, so that the distortions produced in the orbits of the Earth and Mars are not very striking; still they are the greatest (of those depending only on the position of the planets) which these two bodies produce in each other's motions. Here, then, the disturbance, which on a hasty view we might suppose analogous to the *variation* of the Moon, becomes, from the small disproportion of distances, and the near commensurability of the periodic times, much more nearly similar to the slow variation of the elements of orbits.

(160.) It seems quite hopeless to attempt to give a notion of the calculations by which, in all the different cases, the disturbances independent of the excentricities can be computed. It is sufficient to state, that the same methods apply to all, and that they are much more simple than those relating to other points, of which an idea may be given by general explanation.

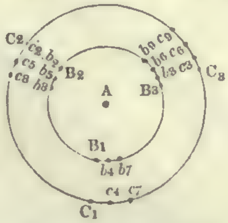
(161.) Let us now consider the inequalities of motion which depend on the excentricities and inclinations of the planets' orbits. The idea that will probably first occur to the reader is this. "If the disturbances of the planets, supposing their orbits to have no independent excentricities, amount only to a few seconds, how is it likely that the small alterations of place, which are produced by the trifling excentricities and inclinations of their orbits, will so far alter their forces upon each other as to produce any sensible difference in the magnitude of irregularities which are already insignificant?" In answer to this we must say, "It is true that these forces, or alterations of forces, are exceedingly small, and those parts of them which act in the same direction for a short time only (as for a fraction of the periodic time of a planet) do not produce any sensible effect. But we can find some parts of them which act in the same manner during many revolutions; and this in many cases where no disturbance can be found, independent of the excentricities, similar to those discussed in (122), &c.; the effects of these may grow up in time to be sensible; and those in particular which alter the mean distance and the periodic time may produce in time an effect on the longitude of the planet (49), very much more conspicuous than that in the alteration of the orbit's dimensions."

(162.) In this consideration is contained the whole general theory of those inequalities known by the name of *inequalities of long period.* They are the only ones depending on the excentricities (besides those similar to the moon's evection) which ever become important.

(163.) To enter more minutely into the explanation, let us take the instance of the long inequality of Jupiter and Saturn: the most remarkable for its magnitude, and for the length of time in which the forces act in the same manner, as well as for the difficulty which it had given to astronomers before it was explained by theory, that has been noticed since the first explanation of the Moon's irregularities.

(164.) The periodic times of Jupiter and Saturn are very nearly in the proportion of 2 to 5 (the periodic times being 4332 days, 17 hours, and 10,759 days, 5 hours), or the number of degrees of longitude that they will describe in the same time, omitting all notice of their excentricities, will be in the proportion of 5 to 2 nearly. Suppose, now, that they were exactly in the proportion of 2 to 5; and suppose that Jupiter and Saturn started from conjunction; when Saturn has described 240 degrees, Jupiter will have described 600 degrees (as these numbers are in the proportion of 2 to 5); but as 360 degrees are the circumference, Jupiter will have gone once round, and will besides have described 240 degrees. It will, therefore, again be in conjunction with Saturn. When Saturn has again described 240 degrees, that is, when Saturn has described in all 480 degrees, or has gone once round and has described 120 degrees more, Jupiter will have described 1200 degrees, or will have gone three times round and described 120 degrees more, and, therefore, will again be in conjunction with Saturn. When Saturn has again described 240 degrees, that is, when it has gone exactly twice round, Jupiter will have gone exactly five times round, and they will again be in conjunction. So that, if the periodic times were exactly in the proportion of 2 to 5, there would be a continual succession of conjunctions at the points whose longitudes exceeded the longitude of the first place of conjunction by 240°, 120°, 0°, 240°, 120°, 0°, &c. Thus, in *fig.* 38, if B_1 is the place of Jupiter at first, and C_1 that of Saturn, Jupiter will have gone quite round, and also as far in the next revolution as B_2, while Saturn has described part of a revolution only to C_2: then Jupiter will again have gone quite round, and also as far in the next revolution as B_3, while Saturn has described part of a revolution to C_3: then Jupiter will have performed a whole revolution, and part of another to B_1, while Saturn has performed part of a revolution to C_1: and then the same order of conjunctions will go on again. If, then, the periodic times were exactly in the proportion of 2 to 5, the conjunctions would continually take place in the same three points of the orbits. This conclusion will not be altered by supposing the orbits excentric: for though the places of conjunction may then be somewhat altered, the conjunctions, after the third (when Saturn has gone round exactly twice, and Jupiter exactly five times), will go on in the same order, and happen at the same places as before.

Fig. 38.



(165.) But the periodic times are not exactly in the proportion of 2 to 5, but much more nearly in the proportion of 29 : 72. This alters the distance of the places of conjunction. We must now suppose Saturn to move through 242°·79, and Jupiter (by the proportion just mentioned) will then have moved through 602°·79, or through a whole circumference and 242°·79, and they will be in conjunction again. The next conjunction will take place when Saturn has moved through double this angle, or 485°·58, or when Saturn has performed a whole revolution, and 125°·58 of the next revolution: and the following conjunction will take place when Saturn has moved through 728°·37, or when Saturn has gone twice round, and has described 8°·37 more. Now, then, the same order of conjunctions will not go on again at the same places as before, but the next three after this will be shifted 8°·37 before the former places, the three following the last-mentioned three will be again shifted 8°·37, and so on. The places of successive conjunction, in *fig.* 38, will be at B_1 C_1, b_2 c_2, b_3 c_3, b_4 c_4, b_5 c_5, b_6 c_6, &c. The shifting of the places of conjunction will take place in nearly the same manner, whether the orbits are excentric or not.

(166.) From this the following points are evident:—

First. In consequence of the periodic times being nearly in the proportion of 2 to 5, many successive conjunctions happen near to three equidistant points on the orbits.

Secondly. In consequence of the proportion being not exactly that of 2 : 5, but one of rather less inequality, the points of conjunction shift forward, so that each successive set of conjunctions is at points of the orbits more advanced, by 8°·37, than the preceding one.

(167.) Let us now inquire how long it will be before the conjunctions happen at the same parts of the orbits as at first.

This will be when the series of points b_4, b_7, b_{10}, &c., extends to B_2. For then the series b_5, b_8, b_{11}, &c., will extend to B_1, and the series b_3, b_6, b_9, &c., will extend to B_2. The time necessary for this will be gathered from the consideration, that in three conjunctions the points are shifted 8°·37: and that the points must shift 120° from B_1, before they reach B_2: and that we may, therefore, use the proportion, As 8°·37 is to 3, so is 120° to 43 nearly, the number of conjunctions that must have passed before the points of conjunction are again the same. And as Saturn advances 242°·79 between any conjunction and the next, he will, at the forty-third conjunction from the first, have described 10440°, or 29 circumferences; and Jupiter, therefore (by the proportion of their periodic times), will have described 72 circumferences. The time, then, in which the conjunctions return to the same points is twenty-nine times Saturn's periodic time, or seventy-two times Jupiter's periodic time, or about 855 years.*

(168.) Now let us examine into the effects of this slow motion of the points of conjunction upon the forces which one body exerts to disturb the other.

(169.) If the orbits had no independent excentricity, it would affect them no further than by the periodical distortion which would take place at every conjunction. There would be nothing in one set of conjunctions, more than in another, which could affect the dimensions of the orbits.

(170.) But if the orbits are not circular, this is no longer true. It is not the same thing whether the conjunctions take place at B_1 C_1, B_2 C_2, and B_3 C_3, *fig.* 39, or at b_1 c_1, b_2 c_2, and b_3 c_3. The distances of the planets are not the same, and consequently the forces which they exert on each other are not the same; also their velocities are different in different parts of their orbits, or at different points of conjunction, and therefore the times during which they can act on each other are not the same. It is true that, in the figure, the distance at $b_2 c_2$ is less than at $B_2 C_2$, while that at $b_3 c_3$ is greater than at $B_3 C_3$; and thus there is a partial compensation in the changes of the effects produced in different points of the orbit. But it can be discovered only by very complete calculations, whether the compensation is perfect or not. The calculations necessary for this purpose are probably the most complicated that physical science has ever given occasion for; and the reader must not here expect the smallest account of them. This only can be stated as a result, that in no instance in the planetary system is the compensation perfect, and that the chances for its being perfect in any case are infinitely small.

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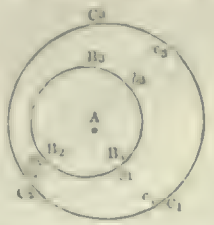
* These numbers are not quite exact: the proportion of 29 : 72 not being quite accurate.

Fig. 39.



(171.) We have here considered the varying influence of one body on the other at conjunction, as depending entirely on the excentricities of the two orbits. But there is another circumstance which may also cause the influence to vary. The orbits may be inclined, and this will affect both the distance of the bodies and the direction in which they attract each other.

(172.) In the case, then, of Jupiter and Saturn, we have the two planets acting on each other with forces which are nearly the same at every third conjunction, but are not exactly the same, and whose variations occupy a period of 850 years. Of these forces, parts are in the direction of the radius vector, and these tend directly to affect the major axes of the orbits described: other parts are perpendicular to the radius vector, sometimes accelerating and sometimes retarding; and these tend (though in opposite ways) to affect the major axes of the orbits. There are, therefore, forces tending to alter the major axes of the orbits, which go through all their changes only in 850 years. During half of this time they tend to make the major axis of Jupiter's orbit less, and that of Saturn's orbit greater; and during the other half they tend to make the major axis of Jupiter's orbit greater, and that of Saturn's orbit less. This coincidence, in time, of the increase of one major axis with the decrease of the other, is the result of investigations that we cannot explain here.

(173.) After the partial compensation that we have mentioned, it will readily be understood that the varying force which produces these effects is small: so small, indeed, is it, that after acting more than 400 years, it has increased (or diminished) the major axis of Saturn's orbit only by $\frac{1}{1350}$th part, and diminished (or increased) that of Jupiter's orbit only by [illegible]th part. These alterations would hardly be discoverable with our best instruments. But during 400 years the major axis of each orbit differs from the major axis during the next 400 years by a part of these quantities. The planet's rate of annual angular motion is, for 400 years, constantly less than its average rate; and for the next 400 years it is constantly greater than its average rate; and in this length of time the inequality in longitude may (49) grow up into a most formidable quantity. In fact, the inequality thus produced in Saturn's longitude amounts to about 48′, by which its true place is sometimes before and sometimes behind its mean place: that in Jupiter's longitude amounts to about 21′. (The greatest inequality of any other planet does not exceed 3′, and the greatest of the planets inferior to Jupiter does not exceed 25″.) The theoretical explanation of these inequalities was first given by Laplace in 1785.

(174.) The magnitude of these inequalities in the motions of Jupiter and Saturn, as we have seen, depends principally on the length of time during which the forces act in the same manner; first, because in this long time they can produce a sensible alteration in the major axis and annual angular motion; secondly, because the two planets move for so long a time with this altered angular motion. But it must also be borne in mind that these two planets are by far the largest in the system; the mass of Jupiter being 300 times that of the earth, and the mass of Saturn being 100 times that of the earth (the next of the planets in the order of magnitude, except Uranus).

(175.) The same general reasoning, by which we have shown that there is a periodical inequality of the major axis of either of these orbits, will also show that there is a periodical inequality in the excentricity and in the place of the perihelion. It will also appear, in the same way, that these effects are the remainder, after partial compensation of effects in different parts of the orbit. Thus if one conjunction happen when Jupiter is going towards aphelion, the effect of Saturn's disturbing force is to pull Jupiter from the sun; and, therefore, by (59), to increase the excentricity of Jupiter's orbit. But it is then perfectly certain that either the next conjunction, or the next but one, or perhaps both these, will happen at a part where Jupiter is going towards perihelion; and then, by (59), the excentricity of Jupiter's orbit is diminished. Similar reasoning applies to the excentricity of Saturn's orbit. It becomes, then, a matter of calculation, whether the compensation is perfect or not. Now it appears, upon investigation, that the compensation is not perfect, but that, while the points of conjunction shift through 120°, the effect of the uncompensated part is, for half the time, to increase the excentricity, and for half the time to diminish it. It appears, also, that there is no necessary connection between the time at which the excentricity is greatest or least, and that when the major axis is greatest or least; so that we cannot assert that when the major axis is greatest the excentricity is greatest, or the contrary, or that the excentricity of one is greatest when that of the other is greatest: all that we can assert is, that the excentricity of each orbit occupies the same time in going through its changes from greatest to least, as the major axis occupies in going through its change from greatest to least. The effect on the planet's distance from the sun, produced by the change of excentricity, is much more considerable than that from the change in the major axis; being for Jupiter $\frac{1}{1130}$ of his whole distance, and for Saturn $\frac{1}{377}$ of his whole distance.

(176.) Similar remarks apply, in every respect, to the motion of the perihelion of each orbit. Each is made to progress during 425 years and to regress during 425 years; but there is no necessary relation between the time when one has progressed furthest and the time when the other has progressed furthest. There is, however, a necessary relation between the change of excentricity and the motion of the perihelion of each orbit: the excentricity of either orbit has its mean value when the perihelion of that orbit has progressed furthest or regressed furthest; and when the excentricity is either greatest or least, the perihelion is at its mean place.

(177.) We have taken the long inequality of Jupiter and Saturn as the most imposing by its magnitude, and the most celebrated for its history (as, before it was explained theoretically, astronomers were completely bewildered by the strange irregularity in the motion of these planets). But there are several others which, in theory, are as curious. Eight times the periodic time of the earth is very nearly equal to thirteen times the periodic time of Venus; and this produces, in the motions of the earth and Venus, a small inequality, which goes through all its changes in 239 years. Four times the periodic time of Mercury is nearly equal to the periodic time of the earth, and this produces an inequality whose period is nearly 7 years. The periodic time of Mars is nearly double of the earth's, and this produces a considerable inequality, depending on the excentricities, &c., besides that mentioned in (159), which was independent of the excentricities. Twice the periodic time of Venus is nearly equal to five times that of Mercury; three times the periodic time of Venus is nearly equal to that of Mars; three times the periodic time of Saturn does not much differ from that of Uranus. Each of these approximations to equality gives rise to an equation of sensible magnitude, and of long period, in the motion of both planets.

(178.) But it will easily be seen that the defect of compensation, on which the effects depend, is much greater in some cases than in others. The conjunctions of the earth and Mars take place at only one point, and the points near it, for several revolutions; those of Venus and Mars take place only at two opposite points and their neighbourhood (as each successive conjunction takes place when Mars has described half a revolution, and Venus 1½ revolution); those of Jupiter and Saturn, as we have seen, at three points; those of Venus and the earth at five points. It is evident that, in the first of these, the whole effect of the change of one point of conjunction has its influence in altering the orbit's dimensions; that in the second there is only the difference between two effects; that in the third there is the mixture of three, which tend to balance; that in the next there is the mixture of five in the same way. The smaller, then, is this number of points, the more favourable are the circumstances (supposing the same length of period for the inequality) for producing a large inequality. This number of points is always the same as the difference between the two least numbers, expressing nearly the proportion of the periodic times. Thus we may expect to find a large inequality when the periodic times of two planets are very nearly in the same proportion as two numbers, whose difference is small.

(179.) We shall now proceed to mention the *secular* variations of the elements of the orbits of planets. By this term is meant those variations which do not depend upon the positions of the planets in their orbits, or the places of conjunction, but merely upon their relative distances and excentricities, and the positions of their lines of apses. They are, therefore, the variations which depend upon the mean or average action of one planet upon another in the long run: all the sensible departures from the secular variation, produced by the irregularity of the action of one planet upon another, being supposed to be contained in the inequalities already discussed.

(180.) First, then, with regard to the mean distance of a planet. If we consider an exterior planet disturbing an interior one (as Saturn disturbing Jupiter), the disturbing force in the direction of the radius vector, by (77), &c., tends sometimes to draw it from the sun, sometimes to draw it towards the sun; but the former is the greater, and we may therefore consider the force as, upon the whole, diminishing the sun's attraction. This, by (46), alters the relation between the periodic time and the mean distance, so that the mean distance is less than it would have been with the same periodic time, had there been no disturbance. If we consider an interior planet disturbing an exterior one (as Jupiter disturbing Saturn), the disturbing force tending to draw it to the sun is greatest; and here the mean distance is greater than it would have been with the same periodic time, had there been no disturbance. But so long as these general effects in the force directed to the sun continue unaltered, the mean distances will not alter (46), &c. Now, upon taking a very long period (as several thousand years), it is easy to see that, if we divide that period into two or three parts, the two planets have in each of those two parts been in conjunction indifferently in all parts of their orbits; that they have had every possible relative position in every part; and that (if we make the periods long enough) the force which one planet has sustained in any one point will be accurately the mean of all which it would sustain, if we estimated all those that it could suffer from supposing the other planet to go with its usual motion through the whole of its orbit. As this mean will be the same for each of the periods, there will, in the long run, be no alteration of the force in the direction of the radius vector, and we may assert at once that the mean distance cannot be altered by it.

(181.) But with regard to the disturbing force acting perpendicularly to the radius vector, the circumstances are different. The mere existence of such a force, without variation, causes an alteration in the mean distance (48); and it is necessary to show that the nature and variations of the force are such that, in the long run, the velocity of the disturbed planet is not affected by it. For this purpose, instead of considering merely the disturbing force perpendicular to the radius vector, we will consider separately the whole force which the disturbing planet exerts on the sun, and the whole force which it exerts on the disturbed planet. Now, the force which it exerts on the sun tends to pull the sun sometimes in one direction and sometimes in another, but on the whole produces no permanent displacement: this force, then, may at once be neglected. The force which one planet has exerted on the other has acted when, for any arbitrary position of the disturbing planet, the disturbed planet has been at every point of its orbit. Since the whole acceleration produced in a long time is the sum of all the accelerations diminished by the sum of all the retardations, we may divide them into groups as we please, and sum each group. Let us, then, group together all the accelerations and retardations produced in one position of the disturbing planet. The disturbed planet having been in every small part of its orbit, during a time proportional to the time which it would occupy in passing through that small part in any one revolution, the various accelerations and retardations will bear the same proportion as if the disturbed planet had made one complete revolution, and the disturbing planet had been fixed. Now, it is a well-known theorem of mechanics, that when a body moves through any curve, acted on by the attractions of any fixed bodies, its velocity, when it reaches the point from which it started, is precisely the same as when it started: the accelerations and retardations having exactly balanced. Consequently, in the case before us, if the disturbing planet had been fixed, and the disturbed planet had made one complete revolution, the latter would, on the whole, have been neither accelerated nor retarded; and, therefore, in the long run, all the accelerations and retardations of the disturbed planet, produced in any arbitrary position of the disturbing planet, will exactly balance. The same may be shown for every position of the disturbing planet; and thus, on the whole, there is no alteration of velocity. Since, then, in the long run, the planet's velocity is not altered, and since (180) the force directed to the sun is not altered, the planet's mean distance will not be altered. This reasoning does not prevent the increase or diminution of the velocity at particular parts of the orbit, and therefore the excentricity and the line of apses may vary; but it shows that, if there is an increase at one part, there is a diminution that balances it at another; and at the point where the orbit at the beginning of a long time and the orbit at the end of that time intersect (which will be at mean distance nearly) the velocity will not be altered.

Our demonstration supposes that the portions of the curves described in different revolutions, for the same position of the disturbing planet, are parts of one orbit, and therefore does not take account of the alteration in the magnitude of the disturbing force produced by the alteration of place which that force has previously caused. This has been taken into account, to a certain degree, by several mathematicians; and it appears, as far as they have gone, that this produces no alteration in the conclusion.

(182.) Secondly, as to the place of perihelion, or the position of the line of apses. The motion of this will depend essentially on the excentricity of the orbit of the disturbing planet. Suppose, for instance, that the orbit of Venus was elliptical and the earth's orbit circular; as the distance of these planets in conjunction is little more than one-fourth of the earth's distance from the sun, the ellipticity of the orbit of Venus would bring that planet at aphelion so much nearer to the earth's orbit, that by far the greatest effect would take place when in conjunction there; and this, by (54), would make Venus' line of apses progress. But if the earth's orbit were more elliptic than that of Venus, and if the earth's perihelion were on the same side of the sun as the perihelion of Venus, it might happen that the principal action would take place at perihelion, and then, by (51), the line of apses would regress. These effects would continue to go on, while the relative position of the lines of apses, and the proportion of the excentricities, remained nearly the same. As, in the long run, conjunctions would happen everywhere, the preponderating effect would be similar to the greatest effect; and thus the secular motion of the line of apses will be constant (till the positions of the lines of apses, &c., shall have changed considerably); its magnitude and direction will depend on the excentricities of both orbits; but if the disturbed planet is the interior, and if the orbit of the other be not excentric, the line of apses will progress. The same is true if the disturbed planet is exterior (the greatest action being then at the perihelion, if the interior orbit have no excentricity, and being directed to the sun).

(183.) Thirdly, as to the excentricity. If the orbit of the disturbing planet were circular, the effect on the excentricity produced by conjunction at the place where the orbits are nearest, would be of one kind before conjunction, and of the opposite kind after conjunction, from the disturbing force in the radius vector; and thus the excentricity would not be altered. The same would happen if both orbits were excentric, provided their lines of apses coincided. Thus it appears that there is no variation of excentricity, except the orbit of the disturbing planet is excentric, and its line of apses do not coincide with that of the disturbed planet. When these conditions hold (as they do in every planetary orbit), a general idea of the effect may be obtained by finding where the orbits approach nearest; then, if we consider the disturbance of the interior planet, since the force draws it from the sun, the excentricity will be increased if it is moving from perihelion, or diminished if it is moving towards perihelion. For the exterior planet, as the force draws it towards the sun, the conclusion will be of the opposite kind. These effects are constant, till the excentricities and the positions of the lines of apses have changed sensibly. The place where the force at conjunction produces the greatest effect on the excentricity may not be strictly the place where the orbits are nearest, but probably will not be far removed from that place.

At the place where the orbits approach nearest, both planets in general are moving from perihelion, or both towards perihelion, so that when one excentricity is increased, the other is diminished.

(184.) For the general stability of the planetary system, the positions of the lines of apses are not important, but the permanency of the major axes and the excentricities are of the greatest importance. The conclusion which we have mentioned as to the absence of secular variation of the major axis, from the action of one planet, applies also to the disturbances produced by any number of planets, and thus we can assert that the major axes of the orbits of the planets are not subject to any secular variation. The excentricities are subject to secular variation, but even this corrects itself in a very long time: when the investigation is fully pursued, it is found that each of the excentricities is expressed by a number of periodic terms, the period of each being many thousands of years. Thus the major axis of the earth's orbit, notwithstanding its small and frequent variations, has not sensibly altered in many thousands of years, and will not sensibly alter; the excentricity, besides suffering many small variations, has steadily diminished for many thousands of years, and will diminish for thousands of years longer, after which it will again increase.

(185.) A remarkable relation exists between the variation of the excentricities (of which that mentioned in (183) is a simple instance), the result of which, as to the state of the excentricities at any time, is given thus: The sum of the products of the square of each excentricity by the mass of the planet, and by the square root of the major axis, is always the same.

Section VIII.—*Perturbation of Inclination and Place of Node.*

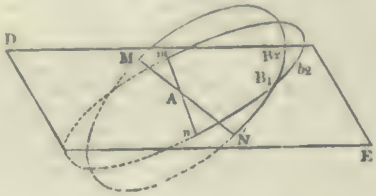
(186.) We have hitherto proceeded as if the sun, the moon, and all the planets, revolved in the same plane—as if, for instance, the sun were fixed in the centre of a table, and all the planets, with their satellites, revolved on the surface of the table. But this supposition is not true. If we suppose the earth to revolve on the surface of the table, the moon will, in half her revolution (we mean while she describes 180°, not necessarily in half her periodic time), rise above the table, and in the other half she will go below it, crossing the surface at two points which, as seen from the earth, are exactly opposite. Venus will, in half her revolution, rise above the table, and in half will sink below it, crossing the table at two points which, as seen from the sun, are exactly opposite; each of the other planets and satellites in like manner crosses the plane at points which, as seen from the central body, are exactly opposite. In different investigations it is necessary to consider the inclination of the plane of revolution or the plane of the orbit to different planes of reference: the line in which the plane of revolution crosses the plane of reference is called the *line of nodes on that plane*; and the angle which the plane of revolution makes with the plane of reference is called the *inclination to that plane*. The plane of reference must always be supposed to pass through the central body.

(187.) The inclinations of all the orbits, except those of the small planets, are so trifling (the largest—namely, that of the moon's orbit to the earth's orbit—being, at its mean state, only 5°) that they may in general be wholly neglected in estimating the disturbance which one planet produces in the motion of another in its own plane. In some cases, however, as in the inequalities of long period, where the effective force is only the small part which remains after a compensation more or less perfect, no alteration of the forces must be neglected; and here, as we have hinted in (171), the inclinations must be taken into account.

(188.) But though the alteration which the inclination produces in the forces that tend to disturb the body's motion *in* its plane may, in most cases, be neglected, yet the force which tends to pull the body *above* the plane, or *below* the plane, cannot be neglected. In almost every case this force will be less than the force tending to disturb the motion in the plane, yet it will be much greater than the alteration which the inclination produces in that force. It is our object in this section to show the nature of the alteration which is produced by the force tending to pull the body from the plane.

(189.) First, then, as to the effect of a force generally which acts perpendicularly to the plane of revolution. (We shall confine ourselves at present to forces which act perpendicularly to the plane, because it is evident that forces which act in, or parallel to, the plane of the orbit, whether in the radius vector or perpendicularly to it, will not cause the planet to depart from that plane.) Let *fig.* 40 be a perspective representation of an orbit, and a plane of reference. Suppose M A N to be the line of nodes at which the plane of the orbit N B_1 B_2 crosses the plane of reference D E; the central body A being in the line of nodes, and the part of the orbit marked by a dark line being above the plane, and that marked by a dotted line being below it. Suppose that the planet has moved from N to B_1, and that at B_1, before it reached the point highest above the plane D E, a force pulls it down towards the plane. After a short time, instead of going to B_2, where it would have been if no force had disturbed it, it will be found at b_2, having described B_1 b_2, instead of B_1 B_2. It is plain that the orbit in which the planet must have moved without a disturbing force, in order to describe B_1 b_2 now, could not be N B_1, but must be such a curve as *n* B_1, crossing the plane D E at a point in the situation of the point *n*. Therefore, if no more disturbing force acts, the planet, which has described B_1 *b*, as if it came without disturbance from *n*, will go on to describe an orbit as if it had come without disturbance from *n*, and will therefore describe an orbit *n* B_1 b_2 *m*, crossing the plane E F in the points *n* and *m*. The line of nodes is changed from M A N to *m* A *n*.

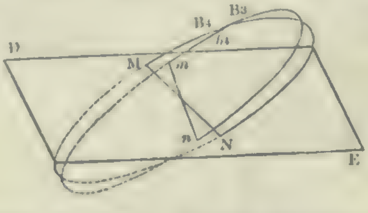
Fig. 40.



(190.) Here the line of nodes has twisted in a direction opposite to the planet's motion, or has *regressed*. The inclination of the new plane is evidently less than that of the old one, since it passes through the same point B, and cuts the plane of reference in a line more distant from B than the line in which the old one cut it, or the inclination is *diminished*.

(191.) Now, if we conceive that at B_3 (*fig.* 41), after the planet has passed the point highest above the plane, a force tends to pull it towards the plane, the planet, instead of going to B_4, will go to b_4, and instead of crossing the plane D E at M, will cross it at *m*; and then, if it is not disturbed again, will proceed in an orbit of which B_3 b_4 *m* is a part, and which will cross the plane D E at the points *m* and *n*. The new line of nodes has twisted here also in the direction opposite to the direction of the planet's motion, or has *regressed*. But the inclination of the new plane is greater than that of the old one, since it passes through the same point B_3, and cuts the plane of reference in a line less distant from B_3 than the line in which the old one cut it, or the inclination is *increased*.

Fig. 41.



(192.) We have, then, this general result: If a force acting perpendicularly to the orbit tends to draw the planet towards the plane of reference, it always causes the line of nodes on that plane to regress: while the planet is moving from a node to the point highest above the plane of reference, it diminishes the inclination to that plane; and while the planet is moving from the highest point to a node, it increases the inclination.

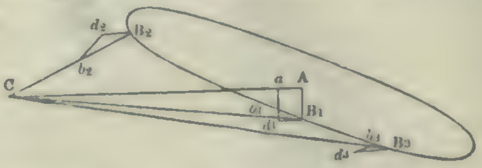
(193.) In the same manner, if the force tends to draw the planet from the plane of reference, it always causes the line of nodes to progress. While the planet is moving from a node to the point highest above the plane, it increases the inclination; and while the planet is moving from the highest point to the node, it diminishes the inclination.

(194.) Similar results would have been obtained if we had considered the action of the force while the planet is in that part of its orbit which is on the other side of the plane D E.

We shall now proceed with the consideration of the force perpendicular to the orbit, which is produced by the attraction of a disturbing body.

(195.) First: it is plain that, if the disturbing body is in the plane of the orbit (produced, if necessary), it will not tend to draw either the central body or the planet out of that plane, and therefore will produce no disturbing force perpendicular to the plane of the orbit. Proceeding, then, with the supposition that the disturbing body is not in the plane of the orbit; and supposing *fig.* 42 to be a perspective view of an orbit B_2 B_1 B_3 (which, to assist our ideas, may be conceived to differ little from a circle) with the disturbing body C out of the plane of the orbit, let us take three points B_1 B_2 B_3, of which B_1 is at the same distance as A from C, B_2 is nearer to C, and B_3 farther from C than A is. Suppose that the attraction of C draws A in a certain small time through the space A *a*, and that when the planet is at B_1, or B_2, or B_3, the attraction draws the planet in the same time through B_1 b_1, or B_2 b_2, or B_3 b_3 respectively. Then (as in (71)) the attraction of C upon the two bodies A and B would produce no disturbance in their relative motions, if it drew them through equal spaces in the same direction. Draw B_1 d_1, B_2 d_2, B_3 d_3 each equal and parallel to A *a*; then if the attraction had drawn B_1 to d_1, there would have been no disturbance, and consequently the real disturbance at B_1 is represented by a force which would have drawn the planet from d_1 to b_1. Similarly, the real disturbances at B_2 and B_3 are represented by forces which would have drawn the planet from d_2 to b_2, and from d_3 to b_3 respectively. Now, since C B_1 is equal to C A, the forces of C upon A and B_1 are equal, and therefore B_1 b_1 is equal to A *a*, and therefore *a* b_1 is parallel to A B_1, and therefore is in the same straight line with b_1 d_1; and consequently at B_1 the whole disturbing force is parallel to the radius vector, and there is no part perpendicular to the plane of the orbit. But at B_2 the planet is nearer to C, the force therefore on the planet is greater, and B_2 b_2 is therefore greater than A *a* or B_2 d_2; also it is more nearly perpendicular to the plane of the orbit than B_2 d_2; and consequently b_2 is farther from the plane of the orbit than d_2; and therefore the disturbing force d_2 b_2 is directed from the plane of the orbit towards the side on which C is. On the contrary, at B_3 the planet is farther from C; the force on the planet is therefore less: and B_3 b_3 is therefore less than A *a* or B_3 d_3; moreover it is inclined more to the perpendicular than B_3 d_3, and consequently b_3 is nearer to the plane of the orbit than d_3; and therefore the disturbing force d_3 b_3 is directed from the side on which C is. Thus we find,

Fig. 42.



(196.) When the central and revolving bodies are equally distant from the disturbing body, there is no disturbing force perpendicular to the plane of the orbit.

(197.) When the revolving body is nearer the disturbing body than the central body is, the disturbing force perpendicular to the plane tends to draw the revolving body out of the plane to that side on which the disturbing body is.

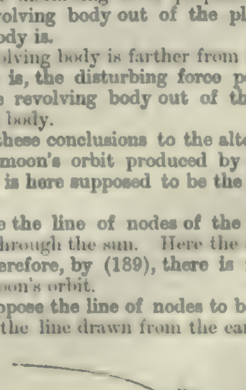
(198.) When the revolving body is farther from the disturbing body than the central body is, the disturbing force perpendicular to the plane tends to draw the revolving body out of the plane to the side opposite the disturbing body.

We may now apply these conclusions to the alteration of the node and inclination of the moon's orbit produced by the sun's attraction. The plane of reference is here supposed to be the plane of the earth's orbit.

(199.) First: suppose the line of nodes of the moon's orbit to be in syzygies, or to pass through the sun. Here the sun is in the moon's orbit produced, and therefore, by (189), there is no disturbing force perpendicular to the moon's orbit.

(200.) Secondly: suppose the line of nodes to be in quadratures, or to be perpendicular to the line drawn from the earth to the sun, as in *fig.* 43. The sun, in the figure, may be considered as being below the plane of the moon's orbit. Also, the moon's distance from the earth being small, the points, at which the moon's distance from the sun is the same as the earth's, are very nearly the same as the points of quadrature, or (in the case before us) they are very nearly the same as

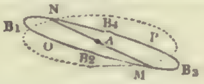
Fig. 43.



the nodes. Consequently, while the moon moves from B_4 through B_1 to B_2, she is nearer to the sun than the earth is, and therefore the disturbing force, by (197), tends to pull her downwards from the plane of her orbit: while the moon moves from B_2, through B_3, to B_4, she is farther from the sun than the earth is, and therefore the disturbing force tends to pull her upwards from the plane of her orbit. In the case before us, then, the disturbing force is always directed towards the plane of reference. Consequently, by (192), while the moon moves from B_4 to B_1, the line of nodes is made to regress, and the inclination is diminished; while the moon moves from B_1 to B_2, the line of nodes regresses, and the inclination is increased; while the moon moves from B_2 to B_3, the line of nodes regresses, and the inclination is diminished: and while the moon moves from B_3 to B_4, the line of nodes regresses, and the inclination is increased. The inclination, therefore, is not sensibly altered in a whole revolution, but the line of nodes regresses during the whole of the revolution.

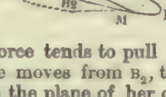
(201.) Thirdly: suppose the line of nodes to be in such a position that the moon passes the line of nodes in going from quadrature to syzygy, as in *fig.* 44. Here the sun is to be considered as below the moon's orbit, and, therefore, while the moon moves from B_4, through B_1, to B_2, the disturbing force tends to pull her down from the plane of the orbit, and while she moves from B_2, through B_3, to B_4, the force tends to pull her up from the plane of her orbit. Therefore, in going from B_4 to N, the force pulls the moon from the plane of reference; and causes thereby a progression of the line of nodes and a diminution of the inclination (193): in going from N to the highest point O, the force pulls the moon towards the plane of reference; and, therefore, causes the nodes to regress, and the inclination to diminish (192); in going from the highest point O to B_2, the force still pulls the moon towards the plane of reference; and, therefore, still causes the nodes to regress, but causes the inclination to increase. Thus while the moon moves from B_4 to N, the force causes the line of nodes to progress, and while she moves from N to B_2, it causes the line of nodes to regress; and, similarly, while she moves from B_2 to M, the force causes the line of nodes to progress; and while she moves from M to B_4, it causes the line of nodes to regress. On the whole, therefore, the line of nodes regresses, but not so rapidly as in the second case. Also, while the moon moves from B_4 to O the inclination is diminished, and while she moves from O to B_2 the inclination is increased; and, similarly, while she moves from B_2 to P the inclination is diminished; and while she moves from P to B_4 the inclination is increased. On the whole, therefore, the inclination is diminished.

Fig. 44.



(202.) Fourthly: suppose the line of nodes to be in such a position that the moon passes it in going from syzygy to quadrature, as in *fig.* 45. Here, also, the sun is below the plane of the orbit produced; and, therefore, from B_4 to B_2 the force tends to pull the moon down from her orbit; and from B_2 to B_4 it tends to pull her up from it. As in the last case it would be seen, that while the moon moves from B_4 to M, the line of nodes regresses; while from M to B_2, the line of nodes progresses; while from B_2 to N, the line of nodes regresses; and while from N to B_4, the line of nodes progresses. On the whole, therefore, the line of nodes regresses. Also, it will be seen, that while the moon moves from B_4 to O, the inclination is diminished; while from O to B_2, the inclination is increased; while from B_2 to P, the inclination is diminished; and while from P to B_4, the inclination is increased. On the whole, therefore, the inclination is increased.

Fig. 45.



The same reasoning would apply, and lead to the same conclusions in every respect, if we supposed the moon's orbit inclined in the opposite direction.

(203.) Now the earth moves round the sun, and, therefore, the sun appears to move round the earth, and in the same direction in which the moon moves round the earth. If then we begin with the state in which the line of nodes is passing through the sun (and in which neither the node nor the inclination undergoes any change, by the first case), we come next to the state in which the moon passes the line of nodes in going from quadrature to syzygy (in which the node regresses and the inclination diminishes, by the third case); then we come to the state in which the line of nodes coincides with the line of quadratures (in which the node regresses rapidly, and the inclination is not altered, by the second case); then we come to the state in which the moon passes the line of nodes in going from syzygy to quadrature (in which the node regresses and the inclination is increased, by the fourth case); and then we come to the state in which the line of nodes again passes through the sun. This is when the sun has described, apparently, half a revolution round the earth (or rather less, in consequence of the regression of the node), and in the other half revolution, the same changes in every respect take place in the same order. The inclination, therefore, is greatest when the line of nodes passes through the sun, or coincides with the line of syzygy; and is least when the line of nodes coincides with the line of quadratures; since it is constantly diminishing while we are going from the former state to the latter, and constantly increasing while we are going from the latter state to the former. This is the principal irregularity in the inclination of the moon's orbit; all the others are very small.

(204.) The line of nodes is constantly regressing at every revolution of the moon, except when the line of nodes passes through the sun. The annual motion which we might at first expect it to have is somewhat diminished by the circumstance that the rapid regression of the line of nodes, when in the position in which the greatest effect is produced, carries it from the line of quadratures more swiftly than the sun's progressive motion only, by making the line of quadratures to progress, would separate them. But as the line of nodes never progresses, the diminution of the motion of the line of nodes thus occasioned is very much less than the increase of the motion of the line of apses (107). Also, as the force acting on opposite points of the orbit tends to produce effects of the same kind, there is no irregularity similar to that explained in (106). Hence the actual regression of the line of nodes, though a little less than might at first be expected, differs from that regression by a much smaller quantity than that by which the actual motion of the line of apses differs from the motion which at first we might expect it to have. The line of nodes revolves completely round in something more than nineteen years.

(205.) The effect of the irregularity in the regression of the nodes, and the effect of the alternate increase and diminution of the inclination, are blended into one inequality of latitude, which depends on the sun's longitude, the longitude of the moon's node, and the moon's longitude. This inequality was discovered (from observation) by Tycho Brahé, about 1590. It may be considered to bear the same relation to the inclination which the evection bears to the excentricity; and, like the evection in longitude, it is the greatest of the inequalities in latitude. It is, however, much less than the evection; its greatest effect on the moon's latitude being about 8′, by which the mean inclination is sometimes increased and sometimes diminished.

(206.) There are other small inequalities in the moon's latitude, arising partly from the changes in the node and inclination, which take place several times in the course of each revolution (200), &c.; partly from the excentricity of the orbits of the moon and the earth, partly from the distortion accompanying the *variation*, and partly from the variability of the inclination itself. We shall not, however, delay ourselves with the explanation of all these terms.

(207.) We shall now proceed with the disturbance of the planets in latitude.

In this inquiry it is always best to take the orbit of the disturbing planet for the place of reference. Now let us first consider the case of Mercury or Venus disturbed by Jupiter. In this case Jupiter revolving in a long time round the sun, which is the central body to Mercury or Venus, produces exactly the same effect as the sun revolving (or appearing to revolve) round the earth, which is the central body to the moon. The disturbing force of Jupiter therefore produces a regression of the nodes of the orbits of Mercury and Venus on Jupiter's orbit; and an irregularity in the motion of each node, and an alteration in the inclination, whose effects might be combined into one: and this is the only inequality in their latitude, produced by Jupiter, whose effects are sensible.

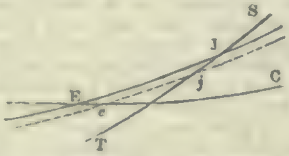
(208.) The other inequalities in latitude, depending on the relative position of the planets, possess no particular interest; and a general notion of them may be formed from the remarks in the discussion of the motion of the moon's node. One case, however, may be easily understood. When an exterior planet is disturbed by the attraction of an interior one, whose distance from the sun is less than half the distance of the exterior planet, and whose periodic time is much shorter, then the exterior planet is always further from the interior planet than the sun is; and therefore, by (195), there is a disturbing force urging it from the plane of reference when the planets are in conjunction, and to it when they are in opposition; and thus the exterior planet is pushed up and down for every conjunction of the two planets. The disturbance, however, is nothing when the exterior planet is at the line of its nodes (195).

(209.) The near commensurability of periodic times, which so strikingly affects the major axis, the excentricity and the place of perihelion, produces also considerable effects on the node and the inclination. The reasoning of (175) and (176) will in every respect apply to this case; the greatest effect is produced, both on the motion of the node and on the change of inclination, when the planets are in conjunction: the gradual alteration of the point of conjunction produces a gradual alteration of these effects, which, however (in such a case as that of Jupiter and Saturn), is partially counteracted by the gradual change of the other points of conjunction: the uncompensated part, however, may, in many years, produce a very sensible irregularity in the elements. If we put the words *line of nodes* for *line of apses*, and *inclination* for *excentricity*, the whole of the reasoning in (175), &c., will apply almost without alteration.

(210.) For the secular variation of the position of the orbit, the following considerations seem sufficient. In the long run the disturbed planet has been at every one point of its orbit a great number of times, while the disturbing planet has been at almost every part of its orbit. The disturbing force is always the difference of the forces which act on the sun and on the disturbed planet. As the disturbing planet, in these various positions, acts upon the sun in all directions in the plane of its orbit, its effect on the sun may be wholly neglected; and then it is easy to see that, whether the disturbing planet be exterior or interior to the other, the combined effect of the forces in all these points on the disturbed planet at one point is to pull it from its orbit towards the plane of the disturbing planet's orbit. (This depends upon the circumstance that the force is greatest when the disturbing planet is nearest.) Consequently, by (192), the line of nodes of the disturbed planet's orbit on the disturbing planet's orbit, in the long run, always regresses. If the orbits are circular, there is no alteration of the inclination, since, at points equally distant from the highest point, there is the same force on the disturbed planet; and, therefore, by (192), the inclination is increased at one time, and diminished as much at another. If the orbits are elliptic, one point may be found where the effect of the force on the inclination is greater than at any other, and the whole effect on the inclination will be similar to that.

(211.) In stating that the nodes always regress in the long run, the reader must be careful to restrict this expression to the sense of regressing on the orbit of the disturbing planet. It may happen that on another orbit they will appear to progress. Thus the nodes of Jupiter's orbit are made to regress on Saturn's orbit by Saturn's disturbing force. The nodes of these orbits on the earth's orbit are not very widely separated; but the inclination of Saturn's orbit is greater than that of Jupiter's. If we trace these on a celestial globe, we shall have such a figure as *fig.* 46, where E C represents the plane of the earth's orbit, J E the orbit of Jupiter, and S T that of Saturn. The orbit of Jupiter, by regressing on Saturn's orbit, assumes the position of the dotted line *j e*; but it is plain that the intersection of this orbit with the earth's orbit has gone in the opposite direction, or has progressed. If the motion of the node on Saturn's orbit from J to *j* is regression, the motion of the node on the earth's orbit from E to *e* must be progression.

Fig. 46.



(212.) There is a remarkable relation between the inclinations of all the orbits of the planetary system to a fixed plane, existing through all their secular variations, similar to that between their excentricities. The sum of the products of each mass, by the square root of the major axis of its orbit, and by the square of the inclination to a fixed plane, is invariable.

(213.) The disturbance of Jupiter's satellites in latitude presents circumstances not less worthy of remark than the disturbance in longitude. The masses are so small, and their orbits so little inclined to each other, that the small inequalities produced in a revolution may be neglected. Even that depending on the slow revolution of the line of conjunctions of the first three satellites, so small is the mutual inclination of their orbits, does not amount to a sensible quantity. We shall therefore consider only those alterations in the position of the planes of the orbits which do not vary sensibly in a small number of revolutions. For this purpose we must introduce a term which has not been introduced before.

(214.) If the moon revolved round the earth in the same plane in which the earth revolves round the sun, the sun's attraction would never tend to draw the moon out of that plane. But (taking the circumstances as they really exist) the moon revolves round the earth in a plane inclined to the plane in which the earth revolves round the sun; and the consequence, as we have seen is, that the line of nodes upon the latter plane regresses, and the inclination of the orbit to the latter plane remains, on the whole, unaltered. The plane of the earth's orbit, then, may be considered a *fundamental plane* to the moon's motion; by which term we mean to express, that if the moon moved in that plane, the disturbing force would never draw her out of it; and that if she moved in an orbit inclined to it, the orbit would always be inclined at nearly the same angle to that plane, though its line of nodes had sensibly altered. The latter condition will, in general, be a consequence of the former.

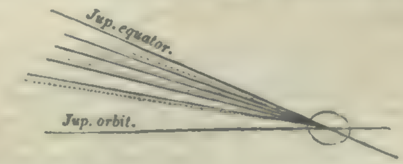
(215.) In order to discover what will be the fundamental plane for one of Jupiter's satellites, we must consider that, besides the sun's attraction, there is another and more powerful disturbing force acting on these bodies, namely, the irregularity of attraction produced by Jupiter's flatness. The effect of this (as we shall show) is always to pull the satellites towards the plane of Jupiter's equator. If Jupiter were spherical, the only disturbing force would be the sun's attraction, tending on the whole to draw the satellite towards the plane of Jupiter's orbit, and that plane would be the fundamental plane of the satellite. If Jupiter were flattened, and if the sun did not disturb the satellite, the irregularity in Jupiter's shape would always tend to draw the satellite towards the plane of his equator, and the plane of his equator would be the fundamental plane of the satellite. As both causes exist, the position of the actual fundamental plane must be found by the following consideration. We must discover the position of a plane from which the sun's disturbing force tends, on the whole, to draw the satellite downwards, and the disturbing force depending upon Jupiter's shape tends to draw it upwards (or *vice versâ*), by equal quantities; and that plane will be the fundamental plane. This plane must lie *between* the planes of Jupiter's orbit and Jupiter's equator, because thus only can the disturbing forces act in opposite ways, and therefore balance each other: and it must pass through their intersection, as otherwise it would at that part be above both or below both, and the forces depending on both causes would act the same way.

(216.) The disturbing force of the sun, as we have seen (82), &c., is greater as the satellite is more distant; the disturbing force depending on Jupiter's shape is then less, as we shall mention hereafter. Consequently, as the satellite is more distant, the effect of the sun's disturbing force is much greater in proportion to that depending on Jupiter's shape. Thus, if there were a single satellite at the distance of Jupiter's first satellite, its fundamental plane would nearly coincide with the plane of Jupiter's equator; if at the distance of Jupiter's second satellite, its fundamental plane would depart a little farther from coincidence with the plane of the equator; and so on for other distances; and if the distance were very great, it would nearly coincide with the plane of Jupiter's orbit. If, then, Jupiter's four satellites did not disturb each other, each of them would have a separate fundamental plane, and the positions of these planes would depend only upon each satellite's distance from Jupiter.

(217.) In fact, the satellites do disturb each other. In speaking of the planets (210), we have observed that the effect of the attraction of one planet upon another, in the long run, is to exert a disturbing force tending to draw that other planet (at any part of its orbit) towards the plane of the first planet's orbit. The same thing is true of Jupiter's satellites. Now, though each of them moves generally in an orbit inclined to its fundamental plane, yet in the long run (when the nodes of the orbit have regressed many times round), we may consider the motion of each satellite as taking place in its fundamental plane. The question, therefore, must now be stated thus. The four satellites are revolving in four different fundamental planes; and the position of each of these planes is to be determined by the consideration that the satellite in that plane is drawn towards the plane of Jupiter's orbit by the sun's disturbing force, towards the plane of Jupiter's equator by the force depending on Jupiter's shape, and towards the plane of each of the other three satellites, by the disturbing force produced by each satellite: and these forces must balance in the long run.

(218.) The determination of these planes is not very difficult, when general algebraical expressions have been investigated for the magnitude of each of the forces. The general nature of the results will be easily seen; the several fundamental planes will be drawn nearer together (that of the first satellite, that of the second, and that of the third, will be drawn nearer to Jupiter's orbit, while that of the fourth will be drawn nearer to Jupiter's equator). The four planes will still pass through the intersection of the plane of Jupiter's equator with that of Jupiter's orbit. Thus, if we conceive the eye to be placed at a great distance, in the intersection of the planes of Jupiter's orbit and Jupiter's equator, and if the dotted lines in *fig.* 47 represent the appearance of the fundamental planes which would exist if the satellites did not disturb each other, then the dark lines will represent the positions of these planes as affected by the mutual disturbances. The inclination of Jupiter's equator to Jupiter's orbit is about $3^\circ\ 5'$; and so great is the effect of his shape, that the fundamental plane of the first satellite is inclined to his equator by only $7''$; that of the second satellite by about $1'$; that of the third by about $5'$; and that of the fourth by about $24\frac{1}{2}'$. Without mutual perturbation, the inclinations to Jupiter's equator would have been about $2''$, $20''$, $4'$, and $48'$.

Fig. 47.



(219.) Having considered the positions of the fundamental planes, we shall now consider the motion of a satellite, when moving in an orbit inclined to its fundamental plane.

(220.) The general effect will be of the same kind as that for the moon. Since the disturbing force which then tends to pull it from the plane of its orbit, tends to pull it towards the fundamental plane (as, supposing the satellite to be on that side of the fundamental plane next the plane of Jupiter's equator, the sun's disturbing force towards Jupiter's orbit is increased, that towards Jupiter's equator is diminished, and so for the others), the line of nodes will regress on the fundamental plane. The inclination on the whole will not be altered. That part of the regression of the nodes which depends on the sun's disturbing force will be greater for the distant satellites than for the near ones; but that which depends on the shape of Jupiter (and which is much more important) will be greater for the near satellites than for the distant ones. On the whole, therefore, the lines of nodes of the interior satellites will regress more rapidly than those of the exterior ones. Their annual regressions (beginning with the second) are, in fact, 12°, 2°, 32′, and 41′.

(221.) But the disturbing force of one satellite upon the others will be altered by the circumstance of its orbit not coinciding with its fundamental plane; and the orbit remains long enough in nearly the same position to produce a very sensible irregularity. To discover the nature of this, we must observe that the force of one satellite, perpendicular to the orbit of another, depends wholly upon the inclination of the two orbits, so that, upon increasing the inclination, the disturbing force is affected. Suppose now, to fix our ideas, the second satellite moves in an orbit inclined to its fundamental plane; what is the kind of disturbance that it will produce in the latitude of the first satellite? First, it must be observed, that when moving in the fundamental planes, the forces depending upon the inclination of those planes were taken into account in determining the position of those planes: so that here we have to consider only the alteration produced by the alteration in the second satellite's place. Next we shall proceed in the same manner as in several preceding instances, by finding what is the motion of the first satellite, related to the motion of the second satellite, which can exist permanently with this inclination of the second satellite. Now, in whatever part the actual orbit of the second is higher above, or less depressed below, the orbit of the first, than the fundamental plane of the second was, at that part there will be a greater force drawing the first satellite up, or a smaller force drawing it down (in the conjunctions at that part), than before. The alteration of force, then, will be generally represented by supposing a force to act on the first satellite, at different points of its orbit, towards the same side of its orbit as the side on which the second satellite's orbit is there removed from its fundamental plane, and proportional to the magnitude of that removal. Now, conceiving the inequality introduced into the motion of the first satellite to be a small inclination of its orbit to its fundamental plane (which is the only inequality of Jupiter's satellites that we consider), the nodes of this orbit cannot correspond to the places where the second satellite is furthest from its fundamental plane; for then, at one node of the first satellite, the disturbing force, before and after passing that node, being great, and not changing its direction, would not alter the place of the node, but would greatly alter the inclination: and at the opposite node, the force acting in the opposite direction would produce the same effect; and thus the permanency of the inequality would be destroyed. We must then suppose the nodes of the orbit of the first satellite on its fundamental plane to coincide with those of the orbit of the second satellite on its fundamental plane. But is the inclination to be the same way, or the opposite way? To answer this, we must consider that the action of Jupiter's shape would tend to make the nodes of the first satellite regress much more rapidly than those of the second; but as our orbit of the first satellite is assumed to accompany the second in its revolution, the disturbing force depending on the second must be such as to destroy a part of this regression, or to produce (separately) a progression of the nodes of the first; consequently, the disturbing force produced by the second must tend to draw the first from its fundamental plane (193). But the disturbing force produced by the second is in the same direction as the distance of the second from the fundamental plane of the second; consequently, the orbit of the first must lie in the same position, with regard to the fundamental plane of the first, in which the orbit of the second lies with regard to the fundamental plane of the second. The same reasoning applies to every other case of an interior satellite disturbed by an exterior; and thus we have the conclusion: If the orbit of one of Jupiter's satellites is inclined to its fundamental plane, it affects the orbit of each of the satellites interior to it with an inclination of the same kind, and with the same nodes.

(222.) Let us now inquire what will be the nature of the inequality produced in the latitude of the third satellite. The same reasoning and the same words may, in every part, be adopted, except that the regression of the nodes of the third satellite, as produced by Jupiter's shape, will be slower than that of the second satellite, and therefore the disturbing force which acts on the third must now be such as to quicken the regression of its nodes, and must therefore be directed towards its fundamental plane. From this consideration we find, as a general conclusion, if the orbit of one of Jupiter's satellites is inclined to its fundamental plane, it affects the orbit of each of the satellites exterior to it, with an inclination of the opposite kind, but with the same nodes.

(223.) The first satellite's orbit appears to have no sensible inclination to its fundamental plane; but those of the second, third, and fourth, are inclined to their fundamental planes (the second 25′, and the third and fourth about 12′), and these are found to produce in the others inequalities such as we have investigated.

(224.) It is only necessary to add, that the disturbance of the first satellite by the second produces an alteration in the action of the first on the second, tending to draw the second from its fundamental plane, and therefore to diminish, by a small quantity, the regression of its nodes. In the same manner, the altered action of the third on the second tends to draw the second towards its fundamental plane, and therefore to increase, by a small quantity, the regression of its nodes. There is exactly the same kind of complication with regard to the disturbances of these bodies in latitude as with regard to those in longitude, explained in (150), &c.

(225.) The only other inequality in latitude, which is sensible, is that depending on the position of the sun, with regard to the nodes of the orbits on the plane of Jupiter's orbit (that is, with regard to the node of Jupiter's equator on Jupiter's orbit), and this amounts to only a few seconds. It is exactly analogous to that of the moon, explained in (205).

SECTION IX.—*Effects of the Oblateness of Planets upon the Motions of their Satellites.*

(226.) In the investigations of motion about a central body, we have supposed that central body to be a spherical ball. This makes the investigation remarkably simple; for it is demonstrated by mathematicians, that the spherical form possesses the following property: the attraction of all the matter in a sphere upon another body at any distance external to it is exactly the same as if all the matter of the sphere were collected at the centre of the sphere. In the investigation of motion about a centre we may therefore lay aside (as we have usually done) all consideration of the size of the attracting body, if that body is spherical.

(227.) But the planets are not spherical. Whether or not they have ever been fluid, still they have (at least, the earth has) a great extent of fluid on its surface, and the form of this fluid will be affected by the rotation of the planet. The fluid will spread out most where the whirling motion is most rapid, that is, at the equator. Thus it appears from theory, and it is also found from measures, that the earth is not a sphere, but a spheroid, flattened at the north and south poles, and protuberant at the equator. The proportion of the axes differs little from the proportion of 299 : 300; so that a line drawn through the earth's centre, and passing through the equator, is longer than one passing through the poles, by 27 miles.

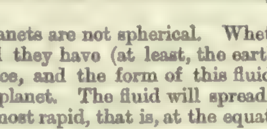
(228.) The flattening of Jupiter is still more remarkable. The proportion of his axes differs little from that of 13 : 14, and thus the difference of his diameters is nearly 6000 miles. In fact, the eye is caught by the elliptic appearance of Jupiter, on viewing him for a moment in a telescope.

(229.) It is our business, in the present section, to point out the general effects of this shape upon the motion of satellites. The agreement of observation with calculation on this point is certainly one of the most striking proofs of the correctness of the theory, "that every particle of matter attracts every other particle, according to the law of Universal Gravitation."

(230.) We will begin with explaining the law according to which an oblate planet attracts a satellite in the plane of its equator.

The spheroid represented by the dark line in *fig.* 48 may be supposed to be formed from the sphere represented by the dotted line, by cutting off a quantity of matter from each pole. To simplify our conception, let us suppose that all the matter cut off was in one lump at each pole; that is, at the points D and E. The attraction of the whole sphere on the satellite B, as we have remarked, is the same as if all the matter of the sphere were collected at A. But the attraction of the part cut off is not the same as if it were collected at A, inasmuch as its distance from B is greater, and as the direction of the attraction to D, or to E, is not the same as that to A. Thus, suppose A D is called 1, and A B is called 10. Since the forces are inversely as the squares of the distances at which the attracting mass is situate, the attraction of the lump D, if at the point A, where its distance from B is 10, may be called $\frac{1}{100}$; but if at D, it must be called $\frac{1}{101}$, since the square of B D is equal to the sum of the squares of B A and A D, that is, to the sum of 100 and 1. Also the direction of attraction is not the same; for, if the attraction of D should draw the satellite through B b, and if b c be drawn perpendicular to A B, the only effective approach to A is the distance B c, which is less than B b in the proportion of B A to B D, or of 10 to $\sqrt{101}$; and, therefore, the effective attraction of D, estimated by the space through which it draws the satellite towards A must be called $\frac{10}{101 \times \sqrt{101}}$. And this is the whole effect which its attraction produces; for though the attraction of D alone tends to draw the satellite above A B, yet the attraction of E will tend to draw it as much below A B; and thus the parts of the force which act perpendicular to A B will destroy each other. We have, then: the attraction of the lump D, if placed at A, would be represented by $\frac{1}{100} = 0{\cdot}01$; but as placed as D, its effective attraction is represented by $\frac{10}{101 \times \sqrt{101}} = 0{\cdot}0098518$. The difference is 0·0001482, or nearly $\frac{1500}{100000}$th of the whole attraction of D, and the same for E. Consequently, the lumps at D and E produce a smaller

Fig. 48.



effective attraction on B than if they were collected at A; but the whole sphere produces the same effect as if its whole mass were collected at A; and, therefore, the part left after cutting away the lumps at D and E produces a greater attraction than if its whole mass were collected at A.

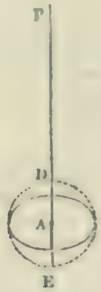
(231.) But it is important to inquire, whether this attraction is greater than if the matter of the spheroid were collected at the centre, in the same proportion at all distances of the satellite. For this purpose, suppose the distance of the satellite to be 20. The same reasoning would show, that the attraction of the lump D, if placed at A, must now be represented by $\frac{1}{400} = 0{\cdot}0025$; but that, if placed at D, its effective attraction is represented by $\frac{20}{401 \times \sqrt{401}} = 0{\cdot}002490653$. The difference now is 0·000009347, or nearly $\frac{375}{100000}$ of the whole attraction of D. Consequently by removing the satellite to twice the distance from A, the difference between the effective attraction of the lump at A and at D bears to the whole attraction of the lump at A a proportion four times smaller than before. And, therefore, the attraction of the spheroid, though still greater than if its whole matter were collected at A, differs from that by a quantity, whose proportion to the whole attraction is only one-fourth of what it was before. If we tried different distances in the same manner, we should find, as a general law, that the proportion which the difference (of the actual attraction, and the attraction supposing all the matter collected at the centre) bears to the latter, diminishes as the square of the distance from A increases.

(232). The attraction of an oblate spheroid upon a satellite, or other body, in the plane of its equator, may therefore, be stated thus:—There is the same force as if all the matter of the spheroid were collected at its centre, and, besides this, there is an additional force depending upon the oblateness, whose proportion to the other force diminishes as the square of the distance of the satellite is increased.

(233.) Now, let us investigate the law according to which an oblate spheroid attracts a body, situate in the direction of its axis.

Proceeding in the same manner as before, and supposing the distance A B to be 10, the attraction of the lump, which at A would be represented by $\frac{1}{100}$, will at D be represented by $\frac{1}{81}$, and will at E be represented by $\frac{1}{121}$, (since the distances of D and E from B are respectively 9 and 11). Hence, if the two equal lumps, D and E, were collected at the centre, their attraction on B would be $\frac{1}{100}+\frac{1}{100}=\frac{1}{50} = 0{\cdot}02$. In the positions D and E the sum of their attractions on B is $\frac{1}{81}+\frac{1}{121} = 0{\cdot}0206100$. The difference is 0·0006100, by which the attraction in the latter case is the greater. Consequently, the attraction of the lumps in the positions D and E is greater than if they were collected at the centre by nearly $\frac{3}{10}$ths of their whole attraction; but the attraction of the whole sphere is the same as if all the matter of the sphere were collected at the centre; therefore, when these parts are removed, they must leave a mass, whose attraction is less than if its whole matter were collected in the centre. With regard to the alteration depending on the distance of B, it would be found, on trial, to follow the same law as before.

Fig. 49.



(234). The attraction of a spheroid on a body in the direction of its axis may, therefore, be represented, by supposing the whole matter collected at the centre, and then supposing the attraction to be diminished by a force depending on the oblateness, whose proportion to the whole force diminishes as the square of the distance of the body is increased.

(235). Since the attraction on a body, in the plane of the equator, is greater than if the mass of the spheroid were collected at its centre, and the attraction on a body in the direction of the axis is less, it will readily be understood, that in taking directions, successively more and more inclined to the equator, on both sides, the attraction successively diminishes. And there is one inclination, at which the attraction is exactly the same as if the whole mass of the spheroid were collected at its centre.

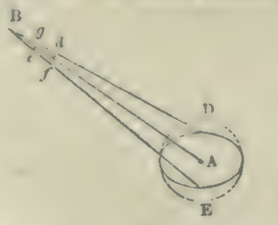
(236). Now, suppose that a satellite revolves in an orbit, which coincides with the plane of the equator, or makes a small angle with it; what will be the nature of its orbit? For this investigation we have only to consider, that there is acting upon the satellite a force, the same as if all the matter of the spheroid were collected at its centre, and, consequently, proportional inversely to the square of the distance, and that, with this force only, the satellite would move in an ellipse, whose focus coincided with the centre of the spheroid. But besides this, there is a force always directed to the centre, depending on the oblateness. One effect of it will be, that the periodic time will be shorter with the same mean distance, or the mean distance greater with the same periodic time, than if the former were the only force. (46). Another effect will be, that when the satellite is at its greatest distance, this force will cause the line of apses to regress, and when at its smallest distance, this force will cause the line of apses to progress, (50) and (53). If this force, at different distances, were in the same proportion as the other attractive force, it would, on the whole, cause no alteration in the position of the line of apses, (for it would amount to the same as increasing the central mass in a certain proportion, in which case an ellipse, with invariable line of apses, would be described; that is, the regression at the greatest distance would be equal to the progression at the least distance. (*See the note to* (98).) But (231) the proportion of this force to the other diminishes as the distance is increased. Consequently, the regression at the greatest distance is less than the progression at the least distance, and, therefore, on the whole, the line of apses progresses. Also, the nearer the satellite is to the planet, the greater is the proportion of this force to the other attraction; and, therefore the more rapid is the progression of the line of apses at every revolution. The progression of the line of apses of the moon's orbit, produced by the earth's oblateness, is so small in comparison with that produced by the sun's disturbing force, that it can hardly be discovered; but the progression of the line of apses in the orbits of Jupiter's satellites, produced by the oblateness of Jupiter, is so rapid, especially for the nearest satellites, that the part produced by the sun's disturbing force is small in comparison with it.

(237.) We shall now proceed with the investigation of the disturbance in a satellite's latitude, produced by the oblateness of a planet.

(238.) First, It is evident that if the satellite's orbit coincides with the plane of the planet's equator, there will be no force tending to pull it up or down from that plane; and, therefore, it will continue to revolve in that plane. In this case, then, there is no disturbance in latitude; we must, therefore, in the following investigation, suppose the orbit inclined to the plane of the equator.

In *fig.* 50, then, let us consider (as before) the effect of the attractions of the two lumps at D and E, in pulling the satellite B perpendicularly to the line A B. Now D is nearer to B than E is; also the line D B is more inclined than E B to A B. If the attraction of D alone acted, it would in a certain time draw the satellite to *d*; and *f d* would be the part of the motion of B, which is perpendicular to A B; and this motion is upwards. In like manner, if the attraction of E alone drew B to *e* in the same time, *g e* would be the motion perpendicular to A B, and this motion is downwards. When both attractions act, these effects are combined; the question then is, which is greater, *f d* or *g e*? Now, since D is nearer than E, the attraction of D is greater than that of E, therefore B *d* is greater than B *e*; also B *d* is more inclined than B *e* to B A; therefore *d f* is much greater than *g e*. Hence, the force which tends to draw B upwards is the preponderating force; and therefore, on the whole, the combined attractions of D and E will tend to draw the satellite upwards from the line B A. But the attraction of the whole sphere would tend to draw it along the line B A. Therefore, when D and E are removed, the attraction of the remaining mass (that is, the oblate spheroid) will tend to draw B below the line B A. In estimating the attraction of an oblate spheroid, therefore, we must consider, that besides the force directed to the centre of the spheroid, there is always a force perpendicular to the radius vector directed towards the plane of the equator, or tending to draw a satellite from the plane of its orbit towards the plane of the planet's equator. If the satellite is near to the planet, the inequality of the proportion of the distances D B and E B is increased, and the inequality of the inclinations to B A is also increased; and the disturbance is, therefore, much greater for a near satellite than for a distant one.

Fig. 50.



(239.) We have seen (215) the effect of this disturbing force in determining the fundamental planes of the orbits of Jupiter's satellites. And from (192), &c., we can infer, at once, that this force will cause the line of nodes to regress, if the orbit is inclined to the fundamental plane, and the more rapidly as the satellite is nearer to the planet. If there were no other disturbing force, the inclination of those orbits to the plane of Jupiter's equator would be invariable, and their nodes would regress with different velocities, those of the near satellites regressing the quicker. In point of fact, the circumstances of the inner satellites are very nearly the same as if no other disturbing force existed, so great is the effect produced by Jupiter's oblateness.

(240.) The figure of Saturn, including in our consideration the ring which surrounds him, is different from that of Jupiter; but the same principles will apply to the general explanation of its effects on the motion of its satellites. The body of Saturn is oblate, and the forces which it produces are exactly similar to those produced by Jupiter. The effect of the ring may be thus conceived:—If we inscribe a spherical surface in an oblate spheroid, touching its surface at the two poles, the spheroid will be divided into two parts; a sphere whose attraction is the same as if all its matter were collected at its centre, and an equatorial protuberance analogous in form to a ring. The whole irregularity in the attraction of the spheroid is evidently due to the attraction of this ring-like protuberance, since there is no such irregularity in the attraction of the sphere. We infer therefore that the irregularity in the attraction of a ring is of the same kind as the irregularity in the attraction of a spheroid, but that it bears a much greater proportion to the whole attraction for the ring than for the spheroid, since the ring produces all the irregularity without the whole attraction. Now, the plane of Saturn's ring coincides with the plane of Saturn's equator, so that the effect of the body and ring together is found by simply adding effects of the same kind, and is the same as if Saturn were very oblate. The rate of progression of the perisaturnium of any satellite, and the rate of regression of its node, will therefore be rapid. In other respects it is probable that the theory of these satellites would be very simple, since all (except the sixth) appear to be very small, and the sun's disturbing force is too small to produce any sensible effects.

(241.) The satellites of Saturn, except the sixth, have been observed so little that no materials exist upon which a theory can be founded. A careful series of observations on the sixth satellite has lately been made by Bessel, from which, by comparing the observed progress of the perisaturnium and regression of the node with those calculated on an assumed mass of the ring, the real mass of the ring has been found. It appears, thus, that the mass of the ring (supposing the whole effect due to the ring) is about $\frac{1}{11}$th of the mass of the planet.

(242.) The effect of the earth's oblateness in increasing the rapidity of regression of the moon's nodes is so small, that it cannot be discovered from observation. But the effect on the position of the fundamental plane is discoverable. We have seen (204) that the moon's line of nodes regresses completely round in 19½ years. The plane of the earth's equator is inclined 23½° to the earth's orbit, and the line of intersection alters very slowly. At some time therefore the line of nodes coincides with the intersection of the plane of the earth's equator and the plane of the earth's orbit, so that the plane of the moon's orbit lies between those two planes; and 9¾ years later, the line of nodes again coincides with the same line, but the orbit is inclined the other way, so that the plane of the moon's orbit is more inclined than the plane of the earth's orbit to the plane of the earth's equator. Now it is found that in the former case the inclination of the moon's orbit to the earth's orbit is greater than in the latter by about 16", and this shows that the plane to which the inclination has been uniform is neither the plane of the earth's equator nor that of the earth's orbit, but makes with the latter an angle of about 8", and is inclined towards the former.

(243.) There is another effect of the earth's oblateness (the only other effect on the moon which is sensible) that deserves notice. The inclination of the moon's orbit to the earth's orbit is less than 5°, and the inclination of the earth's equator to the earth's orbit is 23½°. Consequently, when the moon's orbit lies between these two planes, the inclination of the moon's orbit to the earth's equator is about 19°; and when the line of nodes is again in the same position, but the orbit is inclined the other way, the inclination of the moon's orbit to the earth's equator is about 28°. At the latter time, therefore, in consequence of the earth's oblateness, the moon, when farthest from its node, will, by (235), experience a smaller attraction to the earth than at the former time when farthest from its node. When in the line of nodes, the attractions in the two cases will be equal. On the whole therefore the attraction to the earth will be less at the latter time than at the former. For the period of 9¾ years therefore the earth's attraction on the moon is gradually diminished, and then is gradually increased for the same time. The moon's orbit (47) becomes gradually larger in the first of these times, and smaller in the second. The change is very minute, but, as explained in (49) the alteration in the longitude may be sensible. It is found by observation to amount to about 8", by which the moon is sometimes before her mean place, and sometimes behind it. If the earth's flattening at each pole were more or less than $\frac{1}{300}$th of the semi-diameter, the effects on the moon, both in altering the position of the fundamental plane, and in producing this inequality in the longitude, would be greater or less than the quantities that we have mentioned; and thus we are led to the very remarkable conclusion, that by observing the moon we can discover the amount of the earth's oblateness, supposing the theory to be true. This has been done; and the agreement of the result thus obtained, with that obtained from direct measures of the earth, is one of the most striking proofs of the correctness of the Theory of Universal Gravitation.

GRAVITY, CENTRE OF, is that point at which all the weight of a mass might be collected without disturbing the equilibrium of any system of which the mass forms a part. Thus, if a lever were balanced by means of two solid spheres of uniform density hung at the ends, the equilibrium would still remain if all the matter of either of the spheres could be concentrated at its centre. The centre of the sphere is then its centre of gravity.

When a body is suspended by a string, and allowed to find its position of rest, the centre of gravity is in the line of continuation of the string. If then a body be suspended successively at two different points, and if the lines in which the strings produced would cut through the body can be conveniently determined, the centre of gravity is the point of intersection of the two lines. This process is very easy in the case of a thin flat surface, and the approximation is quite sufficient for practical purposes.

When a surface (or a thin plate) is of uniform density, the centres of gravity and of figure [Centre] are the same. It is needless to say where this falls in the case of a circle, of a square or other parallelogram, or of a regular oval figure. In a triangle it is found by joining the vertex and middle of the base, and cutting the intercepted line into three equal parts, the nearest trisecting point to the base giving the centre of gravity. In a prism and cylinder it is the middle point of the line joining the centres of gravity of the two bases. In a cone or pyramid it is found by joining the vertex and the centre of gravity of the base, and cutting the joining line into four equal parts, the nearest of which to the base ends in the centre of gravity. In a semicircle the distance of the centre of gravity from the centre is about fourteen thirty-thirds of the radius; in a hemisphere this same distance is five-eighths of the radius.

The centre of gravity of two bodies is found by joining their centres of gravity, and dividing the joining line so that the content of the first may be to that of the second as the segment adjoining the second is to that adjoining the first. By the same rule, and by the centre of two bodies thus found and that of a third, the centre of three bodies may be found, taking care to use with each centre the sum of all the contents of the bodies employed in finding it.

GRAVITY, SPECIFIC. [Specific Gravity.]

GREAT CIRCLE or TANGENT SAILING. Although the subject will be found properly introduced under the general head Navigation, the peculiar nature of Great Circle Sailing, and its growing importance to underwriters, shipowners, and therefore to the whole mercantile interests of Great Britain, demand a special notice in this place.

The opening of an expanding and lucrative traffic with the far east of the globe, has called more imperatively for improvements in science and art, which the merchants of old, in their occasionally distant voyages, the less needed. To them indeed one item of daily expense was unknown;—the consumption of coal had not advanced the costs of a voyage to an enormous outlay, nor had the wear and tear of machinery entailed on shipowners disbursements which at this day form so prominent a feature in their aggregate yearly expenditure.

It was to meet this and to render facilities for shortening a voyage already diminished in duration by the use of steam, that attention was attracted to the long neglected practice of great circle sailing.

To explain the principles of this sailing it is only necessary to take an ordinary terrestrial globe, and notice that while some circles usually drawn thereon and called meridians are of equal size, because if the globe were cut in two in the plane of any one of these meridians, the section would pass through the globe's centre, other circles called parallels (as of latitude, declination, altitude, &c.) differ in magnitude. The term great circle only applies to the former: a sphere therefore being cut through on a great circle would be divided into two equal parts. The equator is of this description. If we take a thread and stretch along the equator, say reaching along 80 or 90 degrees of longitude, on tightening the thread it would still lie exactly along the line: such would also be the case on the meridians; but if this be attempted on any of the parallel circles, the thread on being tightened would slip off the parallel in a direction towards the nearest pole, thus forming an illustration of a great circle track; and the farther from the equator this is tried, the more striking would be the difference between the parallel and the track, which thus measures the *nearest distance between the ends of the thread*, and this will be the case wherever a thread is thus applied obliquely on a sphere.

A general belief prevails among merely practical men that this kind of sailing is one of recent development—that its employment has been in consequence of modern discovery; but such is far from the truth. Those who have studied the practice of navigation as given in old authors will be aware that for nearly 150 years before the dawn of this century a knowledge of great circle sailing was not only considered to be a necessary element in the acquirements of a navigator, but a knowledge of its very principles precisely as laid down in the most modern works (so far as regards construction and calculation) was thought an essential part of the educational course of every sea-going merchant captain, and its rules and demonstrations are to be found plainly set forth in such works as Atkinson's, Norwood's, Newhouse's, Gallibrand's, and others of the period of about 1680 to 1720.

Spherical trigonometry was naturally considered indispensable to every one employed in conducting treasure over the surface of a *sphere*, while a knowledge of plane trigonometry was deemed an equally necessary preparation for those whose voyages were so short as to admit of the sides of a triangle on the globe being for ordinary purposes considered as straight lines but the teaching of spherics to the navigator falling into disuse (by some extraordinary misconceptions), great circle sailing gradually became neglected, until for many years it was omitted in the standard works on navigation altogether. Even the attempt of Dr. Kelly, the mathematical examiner at the Trinity House nearly 50 years since, to renew the study of spheric projection, resulted in failure. Thus, while the sea officers of other nations are well prepared in that which forms not only the basis of great circle sailing, but of nautical astronomy, the energetic and intelligent mariners of England, although progressing in all else, were doomed for a time to wade in the pursuit of principles through works which as regards theory are somewhat too elaborate, and with respect to the rules of spheric construction are quite inadequate, for the mere navigator.

Such was pre-eminently the state of things when the late skilful and lamented Lieutenant Henry Raper, R.N., produced his 'Practice of Navigation,' which forms the present text book of the Royal Naval service, and of the higher classes of merchant navigators. But even in this admirable work the doctrine of spheric construction has been omitted as evidently forming no supposed essential in a sea officer's training.

The name of Raper must however be conspicuous as the regenerator of great circle sailing. In his work he gives excellent formulæ, but the use of logarithms *arising from rules not understood* by the uninitiated entails an effort of memory which is injuriously allowed to supplant the satisfaction which a conscious knowledge of principles would so unceasingly furnish. Notwithstanding this, Raper's solution of the "wearisome problem" of the great circle is eminently concise and practical, and for those who are content with spheric calculation, nothing more can be desired.

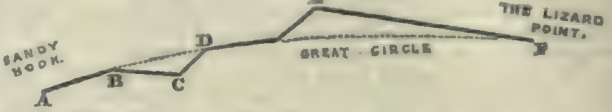
Soon after Raper's work appeared, Mr. J. T. Towson, examiner in navigation at Liverpool, devised a set of tables, by means of which, and an ingeniously contrived diagram called a "linear index," together with the aid of dividers and scales, he so greatly simplified the matter as naturally to affect the commerce of the country, inasmuch as voyages which formerly occupied nearly 150 days were principally by means of great circle sailing, and, together with improvements in ship-building [CLIPPER], performed in about 70 to 80 days. Hence the subject has become one of large pecuniary moment; and it must here in justice to Mr. Towson be stated, that he generously presented to the Admiralty for public use the tables which had been constructed by him through years of very great labour. He has subsequently been enabled to further facilitate the question by adding to his tables, in 1854, a column containing the means of ascertaining at once the distance between a ship and her destined port.

Various attempts have been lately made to supersede these tables: one of these deserves particular mention, not only from the elegance of the means employed, but from its leaving so little to be desired, although that little was important. It occurred to the Rev. Hugh Godfray, M.A., and to a merchant captain, Mr. Bergen, at about the same period, that a chart constructed on the gnomonic projection [GNOMONIC PROJECTION] would at once show the great circle track by laying any straight edge along the two given places: this certainly shows the track with great accuracy; but here again the aid of a second diagram, formed, too, by curves which convey at sight no elucidation of principles, was required in finding the "course and distance."

Popular errors exist on this question which are worthy of special notice. Navigators are accustomed to use charts constructed on Mercator's projection, wherein all bearings are taken as straight lines, and these straight lines cross all the meridians at the same angle, and therefore offer a convenient mode of sailing and a ready means of finding a course and distance; but from reasons already given, as explained in applying a thread to a globe, the same error in actual distance must exist on Mercator's charts, where the parallels are represented as straight lines, as are found on the surface of the globe itself; for a parallel of latitude in neither case exhibits the nearest track between two places lying on it: therefore, if we wish to show on a Mercator's chart the nearest distance between such two places, it can only be represented by a curve, and as a mathematical line is that which is the nearest distance between two points, those who forget that the straight lines on the Mercator's chart are, to answer a specific purpose, themselves actually distortions, are liable to doubt the soundness of the principle of great circle tracks.

And, again, a multitude of navigators at this day deny the possibility of sailing on a great circle curve, because, say they, such would require a continual change of course. As well may it be said that, because of the difficulties attending the quadrature of the circle, the use of the circle in ordinary mathematical computations is fallacious. This widely existing misapprehension would at once be demolished were this method of navigation called "tangent sailing;" such it really is; and the change of name was first proposed to the astronomer-royal in 1857 by Mr. Saxby; for it is the peculiar property of great circle sailing that, in contradistinction to Mercator's, no two meridians are crossed at the same angle. All that need be done, therefore, by a navigator is, to sail *as near to his great circle track as convenient*, and each *separate* course will be a *tangent to his track;* and the shorter those tangent courses can be made the more will the duration of a voyage be diminished. But where a method is used, the principles of which are little understood (for the terms lat. of vertex, long. of vertex, &c., suggest a difficulty to the untrained student), a ship standing too long on one course is liable to be found hundreds of miles northward or southward of her desired position; and this will be found generally to arise from the captain's using too frequently during the passage the same latitude of vertex with which he started, *and on which he calculated his courses for the voyage before leaving England.* The following figure will illustrate this. It is the memorable and unexaggerated track of a celebrated clipper across the Atlantic to England in the autumn of 1856, one of the then shortest passages on record.

Fig. 1.

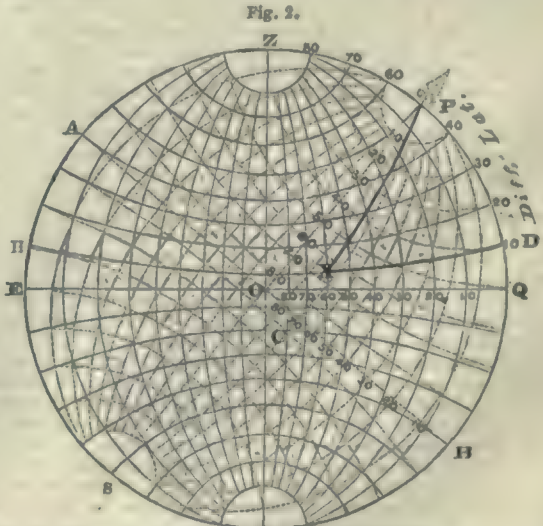


In the above it will be seen that on the ship's being found at C (at some distance from the dotted great circle A F between the two places), she was, to save calculation, hauled up for the great circle track, instead of being navigated on a newly-found track, and with, of course, a newly-found "latitude of vertex" in the tables used; while, on arriving at E, whither a heavy swell and S.E. wind had driven her, the captain abandoned his former track, and, prudently forming another, as at E F, completed his brilliant passage upon it with credit.

From this it appears that facilities were wanted whereby to further simplify the finding of a great circle course and distance; and as the astronomer-royal, the Trinity Board, and the Local Marine Board of London, and the highest authorities, approve of the use of the "spherograph" as the readiest and most intelligible means of navigating on a great circle, a case in illustration of its applicability is given below.

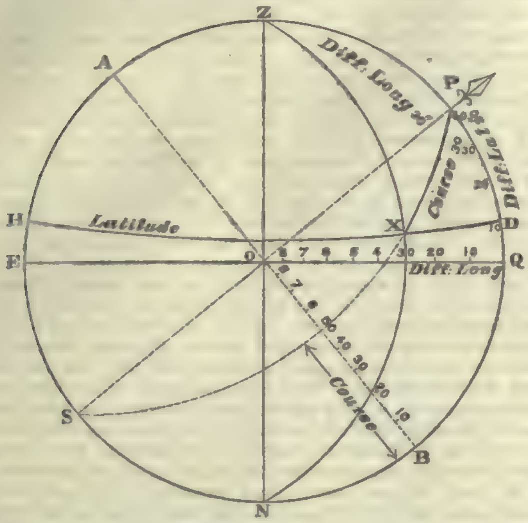
If we take two hemispheres on the stereographic projection, each having the usual meridians and parallels drawn thereon, and attach them so that they revolve concentrically, the *upper one* being made of some transparent material, we have the powerful patented instrument called the "spherograph." Its use in spheric navigation is as follows: suppose a ship to be in latitude 50° N., and bound to a port which is in lat. 10° N. and 60° difference of longitude westerly. The *figure* 2 will show the problem as *set* by the spherograph, in which the dotted lines are supposed to be *seen through* the upper sphere. The only manipulation required was the moving the under pole P to the ship's latitude, E Q being the equator. Then P D would evidently be the difference of latitude, and D X the difference of longitude, while P X would give at once the great circlet rack, and the angle X P D would show at once the course to be sailed; and counting the dotted parallels of the under sphere which cross P X, we evidently read off the number of degrees in the distance between P and X, which multiplied by 60 gives the nearest distance in geographical miles. Hence the course X P D (measured at 90° from the angular point P), or at C B, would be about 72½° (or S. 72½° W., because the diff. of lat. and diff. of long. are southerly and westerly by question), and the distance X P = about 63½° × 60 = 3810 miles.

Fig. 2.



Suppose, in addition, the ship, when next able to ascertain her position was found to be in latitude 40° (instead of 50°), and having only 30° of longitude to make. We should now, as in *fig.* 3, set the under pole to 40° north latitude and (omitting all unnecessary lines for the sake of clearness) the line D X would represent the difference of longitude, 30° and P X the distance, while the spheric angle X P D would be the

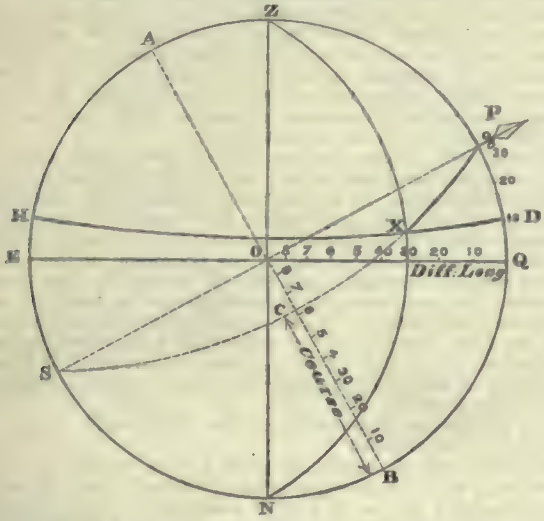
Fig. 3.



required course; and being measured on C B, would give 50°, or (S. 50° W.), and the distance P X would be found as in *fig.* 2.

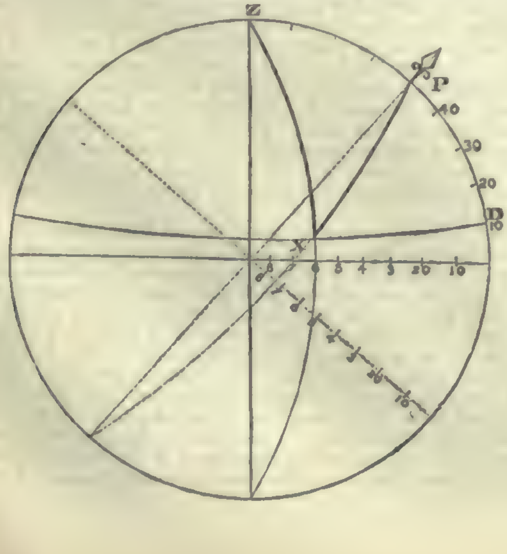
Suppose, further, the next ascertained position of the ship to be in lat. 30° N., and the diff. of long. 30° (as before). The under pole P being

Fig 4.



moved to 30° N., would show the problem as in *fig.* 4, which would be solved as in the above, giving the course about 60° or S. 60° W.

Fig. 5.



The mathematician will have noticed that the useful problem of great circle sailing is solved in the spherograph by means of a triangle, differing from that generally used in its solution by calculation, an example of which it is essential to give. For while by the latter we use the two zenith distances with the difference of longitude, in the instrument we simply take the latitude in, and the latitude bound to, and the difference of longitude. Instead of using triangle X Z P as in calculation, we use the rational triangle X P D.

Fig. 5 represents the problem given in *fig.* 2, as adapted to the following computation :—

Let Z P be the co. lat. 40°, and Z X be the co. lat. 80°, and the angle P Z X be the diff. of longitude 60°. To find the distance P X, and X P Z, the complement of the first great circle course.

Z P = 40° . . 40° Angle P Z X = 60°
Z X = 80 . . 80
30 ½ contained angle.
120 sum . 40 diff.
60 ½ sum . 20 ½ diff.

As sine ½ sum 2 sides	60°	ar. co.	0·062469
To sine ½ diff. . .	20	„	9·534052
Cot. ½ contained angle	30	„	10·238561

9·835082 = tang. ½ diff. of the other two angles, or 34° 22′.

As cos ½ sum 2 sides .	60°	ar. co.	0·301030
To cos ½ diff. . .	20	„	9·972986
Cot. ½ contained angle	30	„	10·238561

10·512577 = tang. ½ sum of the other two angles, or 72° 55′

½ sum 72° 55′
½ diff. 34 22
Sum 107 17 = co. course X P Z, and 180°—107° 17′ = the course Q P X, or 72° 43′.
Diff. 38 33

∴ To find the distance P X—

As sine X P Z .	107° 17′	ar. co.	0·020065
To sine Z X .	80	„	9·993551
So sine P Z X .	60	„	9·937531

9·951147 = sine 63° 20′
60
3800 the distance in geographical miles.

The instrument, however, has this advantage over all other methods, namely, it takes the simple data alone as they occur in practice, without there being necessity for the terms hitherto found convenient, such as lat. of vertex, long. from vertex, &c., or indeed even the co. latitudes, co. courses, &c., and the tyro is thus only using terms in the spherograph which *he thoroughly comprehends.*

We have now shown that it is really easier to navigate on the great circle than by any other method. The applying of parallels to a common chart in order to obtain what is actually an *erroneous* course, occupies more time than using the spherograph to find the course which leads *directly* to the place bound to.

If anything could be more simple, it is to be found in the tables which accompany the instrument, and which are derived from spheric calculation, and have no connection with the diagrams, except that they verify the accuracy of instrumental projection. We give an example as worked in these tables. Taking the question in the above *fig.* 4, namely, lat. of the ship, or "*Lat. in*" 30°, diff. of long. 30°, diff. of lat. 20°, we will suppose a block of figures (omitting such as are unnecessary for our illustration) to be as under ;—

Ship's lat. in	Diff. of lat.	Diff. of longitude. 5°	10°	15°	20°	25°	30°	35°	40°	45°	50°	55°	60°, &c.
30°	5°	..	..	..	..	..	..	..	..	..	..	..	..
	10	..	..	..	..	..	..	..	..	..	..	..	..
	15	..	..	..	..	..	..	..	..	..	..	..	..
	20	..	..	..	..	..	60	..	..	..	..	..	..
	25	..	..	..	..	..	..	..	..	..	..	..	..
	30	..	..	..	..	..	..	..	..	..	..	..	..
	&c.												

The intersection of the vertical and horizontal lines at "60," having reference to the data, shews the great circle course to be S. 60° W., as measured at B C (*fig.* 4).

The not easy consideration of composite sailing [SAILINGS], is henceforth entirely superseded by the following general rule in determining the course of a voyage, and its importance to maritime commerce cannot be over-rated. A navigator with the chart before him, and possessing a spherograph, will in future reason thus with himself: "Being anxious to make the shortest possible voyage, I must not let great circle sailing take me into difficulties as to dangers, baffling winds, ice, &c.; no, I shall for very many reasons like to place my ship *there* and *there*, on my route" (at the same time marking dots on his chart to indicate such places). We need only imagine P in *fig.* 2, to be one of those dots, and X another,—always supposing one of the places to lie on the primitive circle, which in all cases represents the ship's meridian—and the extreme simplicity of this new method by spherograph, to the total exclusion of what has been called "composite" sailing, will be at once apparent.

Hitherto whatever obstacles may have prevented the general renewal of the practice of great circle, or tangent, navigation, a knowledge of such obstructions has been confined almost to navigators alone; but henceforward (and our so thorough investigation of this important subject as a national question bearing with weight upon extensive interests, has been with this object) it will remain with shipowners and underwriters to see that their treasure is conveyed from place to place in the *shortest possible time;* for to take a melancholy example, it must not be forgotten that had the unfortunate "Royal Charter" been able, by any extra facilities possessed by her late accomplished Captain, to reach Point Lynas even *twelve hours earlier*, the awful catastrophe which desolated so many homes, and wrung so many hearts, would most probably have been averted.

GREAVES. [ARMOUR.]

GRECIAN ARCHITECTURE. The most ancient constructional remains in Greece are the rude pre-historic masses of masonry known as Cyclopæan, from their being attributed by early tradition to the fabulous Cyclopes. They consist chiefly of walls formed of huge shapeless blocks of stone, having the interstices filled up with smaller but equally rude blocks. Of a less uncertain but still remote period are the Pelasgic remains, which, though remarkable rather as constructive works than as works of art, are yet for many reasons not devoid of interest in the history of architecture. They belong however to a non-Hellenic people, and have little affinity with the true Grecian architecture; and therefore will be noticed under a separate head. [PELASGIC ARCHITECTURE.]

Without here entering upon an examination of the history of Grecian architecture, we may briefly observe that it is now generally admitted that, although in its ultimate development it is beyond dispute the creation of the Hellenic mind, the germs of it were derived from the architecture of older nations: its grander elements and more solid proportions from Egypt; its lighter characteristics and more ornate features from Asia. The great distinction of Grecian architecture lies in its orders: these are the Doric, Ionic, and Corinthian. Of these the Doric is the oldest, and it is noteworthy not only that in the oldest known example, a temple at Corinth of the 7th century, B.C., are the proportions far more massive and the whole more pervaded by Egyptian feeling than in later temples, but that there still exists a tomb at Beni Hassan in Nubia, supposed to be of the age of Rameses II., at the entrance of which are two fluted columns clearly the prototypes of the Grecian Doric; while, as Sir G. Wilkinson has shown ('Ancient Egyptians,' vol. ii. p. 125, and Plate vii.), the characteristic Doric *fret* border was also a common Egyptian ornament. The more graceful Ionic order, on the other hand, may clearly be traced to Asia. As Mr. Fergusson has pointed out, there occur in the ruins of Persepolis several columns which have the Ionic volutes, but placed vertically instead of horizontally. On slabs found in Khorsabad by M. Botta, however, and in others brought from the same locality, and now in the British Museum, are sculptured representations of buildings with columns crowned with volutes precisely as in the Greek Ionic. The Ionic guilloche ornament is also found both at Persepolis and Khorsabad. The latest of the three Greek orders, the Corinthian, is equally a derived one with the others. As was shown in the article COLUMN, the bell of the Corinthian capital of the temple of Apollo at Bassæ, near Phigaleia, closely resembles the Egyptian capitals placed alongside it; and in one of the two remaining Corinthian buildings in Greece, the Tower of the Winds, at Athens, there are no volutes to the capitals, and the leaves of water-lilies adhere, as in Egyptian examples, close to the bell.

But if the architecture of the Greeks, like that of every other people, was derived rather than invented, all that gave to it its life and power is its own. The exquisite feeling for beauty of proportion, majestic simplicity of form, truth and purity of expression, and perfect adaptation to its purpose, all those higher constructive and æsthetic qualities, in short, which place it so far above the architecture of all other countries, only Greece can lay claim to.

The religious edifices of a people are nearly always the surest indication of the state of their architectural tastes and ability. Fortunately perhaps the temples are almost the only buildings of ancient Greece which have come down to the present day in a sufficiently uninjured condition to permit of our forming a fair estimate of them. The oldest left is believed to have been built about the middle of the 7th century, B. C.; one or two others are of the 6th century, but the finer examples belong to the 5th and 4th centuries, B. C. The classes, forms, and architectural character of the temples will be described under that title. [TEMPLE.] The public buildings devoted to secular purposes of which any remains exist consist chiefly of theatres, agora, thermæ, &c., and these too are noticed elsewhere. [THEATRE; FORUM; BATH, &c.] Of the palatial residences and private houses, only imperfect written descriptions are left. One or two small monuments however, as the Choragic Monument of Lysicrates, and the Tower of the Winds—both comparatively late works and both Corinthian in style—remain as proofs of the exquisite taste and skill which the Greeks could exert on their less important secular structures.

Greek architecture differs from all subsequent styles in being non-arcuated. Whether the Greeks were acquainted with the arch or not, they did not employ it in their public buildings. The great constructive feature is the beam. Greek architecture consequently is essentially *horizontal* in principle: its primary lines are horizontal, its secondary vertical. Hence stability, solidity, are its constant characteristics. Yet though rectilinear in appearance it is not strictly so in fact. So sensitive was the Greek eye to the slightest deviation from perfect beauty of expression, that the architects resorted to a singularly refined contrivance to overcome an optical illusion so small that no other people probably would ever have noticed it. Right lines when protracted far above or on either side of the spectator no longer seem perfectly straight, but are slightly bent in accordance with the laws of perspective. Contrasting right lines, and even contrasts of light and shade in like manner cause an appearance of deflection. To remedy these and other corresponding effects, it has been recently found that not only did the Greeks, as has long been known, give their columns a slight *entasis*, or swell near the middle, but they made the boundary line a delicate parabolic curve; and instead of placing the axes of the columns as was always supposed quite vertical, they inclined them in a small measure inwards. They also gave to the pavements on which the columns rested, and the steps of their temples, a minutely convex character, the rise in the centre being about three inches in a hundred feet. Further, the horizontal lines of the entablature were curved in a precisely correspondent manner, and other minor adjustments made. But all these minute curves were executed with such exquisite knowledge and skill, that the effect was simply that of rendering the spectator unconscious of any deviation from a mathematical right line; and it is only by the most careful observation that the contrivance is even now detected. The discovery of these curves was made by Mr. J. Pennethorne, in 1837, and soon afterwards (we believe independently) by Messrs. Hofer and Schaubert; but their existence was placed beyond doubt, and the principles upon which they were carried out clearly evolved by Mr. Penrose, who spent a considerable time in Greece investigating the subject and making careful and repeated admeasurements: the results of his researches were embodied in his 'Principles of Athenian Architecture,' published by the Dilettanti Society in 1851. These refined optical corrections seem to have been always most perfectly developed in temples of the Doric order, but they are found more or less in most others.

It is in Doric temples too that another great artistic feature was most effectively developed, namely that of the introduction of sculptural ornamentation. In all Greek temples sculptured ornament was freely introduced, but in the nobler Doric temples it appears in its greatest perfection. In the cella were introduced friezes in low relief; in the metopes alti-relievi, and in the tympanum of the pediment statues entirely detached. And that these were, at least in some instances, the masterworks of the sculptor's art we have evidence in those marvellous reliques which once adorned the Parthenon, and are now the glory of the British Museum [ELGIN MARBLES], while that their adjustment to their respective places was the result of a perfect knowledge of sculpturesque effect may be seen by a reference to the article ALTO-RELIEVO.

The polychromatic decoration of the temples will be spoken of elsewhere. [POLYCHROMY.]

The three Greek orders characterise three periods in Grecian architecture much as the three styles of Pointed Gothic characterise three important phases in English architecture. Doric, the oldest, corresponding in seniority and character to our First Pointed, the true English Doric, is marked by a sober grandeur and simple dignity, yet withal is preeminently beautiful. The Ionic, which follows in order of time, more graceful, easy, and flowing in style, corresponds not inaptly to our Second Pointed or Decorated. While the luxuriant Corinthian, the product of the later years of Greek art, and the herald of its decline, finds its parallel in our florid Third Pointed or Perpendicular. [GOTHIC ARCHITECTURE.] But in one respect there was a broad difference. The Gothic of either class was the exclusive style of its epoch. The Decorated did not tolerate the Early English, nor the Perpendicular the Decorated. The Greek orders, though they were the product of different ages continued to flourish contentedly together. Ionic did not suppress Doric nor Corinthian Ionic, but the elder and the younger simultaneously filled the places for which each seemed most fitted.

Before noticing somewhat more in detail the orders of Grecian architecture, it is necessary to explain that what is termed an Order consists of two principal divisions, the *Column* and the *Entablature*—*i. e.*, the upright support and the horizontal mass supported by it. The Column is again divided into *Base*, *Shaft*, and *Capital* (except in the Doric order, where the shaft rests immediately upon the flooring.) The Entablature is also divided into three parts—the *Architrave*, or Epistylium, *Frieze*, and *Cornice*. These together constitute the Order; which is further distinguished as belonging either to the Doric, the Ionic, or the Corinthian style, according to certain general proportions and characteristic embellishments. The scale for the proportions—that is, not the actual but the relative dimensions of the different parts compared with each other—is taken from the lower diameter of the shaft of the column, which is divided into two modules or sixty minutes. Modern systematisers, who have laid great stress upon proportions, have, contrary to the practice of the Greeks themselves, attempted to fix certain invariable proportions for each order; and some have maintained that by them, quite as much as by peculiarities of detail and embellishment, the character of an order is determined. In regard to proportions, however, even greater discrepancy is found between different examples of the same order, than between two distinct orders. We must therefore attend to certain indicial features and marks by which the particular order may be immediately recognised; thus the absence of base or mouldings at the bottom of the column, the plain capital composed of merely an echinus and abacus, and a triglyphed frieze, enable us to pronounce at once that the order is the Doric. In like manner the voluted capital, or the foliaged one, as distinctly denotes that it is either Ionic or Corinthian. In regard to the two last-mentioned, the principal distinction between them is confined to the capital; there being no other determinate difference between the columns or the entablatures of the one or the other. Were we to see only the shaft of the column, we should be able to decide from that alone whether it were Doric or not; the flutings peculiar to that order being broad and shallow, and forming sharp ridges or arrises on the circumference of the shafts; whereas in the other two they are narrower and deeper, rounded at their extremities, and divided from each other by fillets or spaces left between the channels on the surface of the shaft. In like manner were we to see the fragment of an architrave, we could pronounce with tolerable certainty whether it was Doric or not; although in the latter case not quite so clearly whether it was Ionic or Corinthian. The Doric architrave consists of a single plain face surmounted by a broad fillet, here termed the tænia, to which another fillet with small cylindrical guttæ or drops is attached beneath each triglyph; but the architraves of the other two orders are divided into (generally) three faces or faciæ, slightly projecting one above the other, and crowned by curved mouldings, sometimes plain, but more frequently enriched. By attending to these few simple and obvious distinctions, no one can feel any difficulty in ascertaining the particular order to which a building belongs. Illustrations are given of the details of the entablatures of the several orders under COLUMN.

Peristyle of the Parthenon.

Doric Order.—In attentively examining the Grecian Doric, we can hardly fail to note what admirable taste and study of effect it exhibits throughout, and how every part is made to conduce to the character of the whole. The columns are of short proportions, the entablature deep; the former have no bases, which, owing to the narrowness of the inter-columns, would have proved highly inconvenient, and instead of producing an air of finish would rather have occasioned heaviness. The proportions themselves are such as to reject any addition of that kind at the lower extremity of the column, because the difference between the upper and lower diameter—which, owing to the shortness of the shaft, occasions so visible an inclination as to produce the effect of tapering upwards—causes it also to appear to spread out below in such manner that the lower extremity becomes a sufficiently wide basis. This inclination is further rendered more apparent than it would be by the outline alone of the column, owing to the lines being repeated in the fluting. The fluting, while it diminishes the heaviness, produces great variety of light and shade in every direction; and the mode of fluting peculiar to this order is admirably in unison with the expression of all the rest, the channels being wide and shallow, and separated from each other by mere ridges on the surface; both which circumstances contribute to that breadth and simplicity which pervade the other parts. No less appropriate and well imagined is the capital, which consists of little more than an echinus and deep square abacus above it; the former expanding itself out from the neck, or upper part of the column, until its diameter becomes equal to that of the foot of the column: in reality, it is something greater, but not more so than is requisite to counteract the apparent diminution caused by the greater distance from the eye. Thus harmony is kept up between both extremities of the column, verticality is restored, the projection above (as in the case of the sloping wall and coved cornice of Egyptian structures) is made to restore perpendicularity by adding just as much as had been taken away by the diminution of the shaft upwards, and a play, variety, and contrast are produced, unattainable by any other mode.

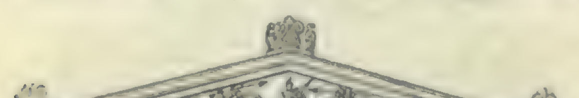
The architrave is plain and deep, well proportioned both as to the weight which it has to bear and to the column below, its average height being equal to the upper diameter or narrowest part of the column. The width of its *soffit*, or under side, is about a medium between the two extreme diameters, so that it overhangs the upper part of the shaft; yet it is not so broad as the abacus of the capital, which by opposing a greater surface to it appears better calculated to support its pressure. The frieze is generally of the same dimensions as the architrave, very rarely deeper, in some examples not so deep. The *triglyphs* which decorate it, and are peculiar to the order itself, are upright, slightly projecting tablets (in width rather more than half the lower diameter), channelled with two grooves or glyphs (γλυφαί), and with a half groove chamfering off each of its outer edges. The spaces between these ornaments, which were originally intended to represent the extremities of the beams (whether stone or timber) resting upon the architrave and forming the inner roof or ceiling are

The Parthenon.

square, or nearly so, and are distinguished by the name of *metopes* (μετόπαι; *i. e.* openings or intervals. They are in fact so many small panels, and were generally filled with sculpture in bas-relief, although there is hardly an instance of the kind in any of the numerous modern imitations of the Greek Doric. Beneath each triglyph is a series of small *guttæ*, or cylindrical drops, attached to a fillet, just under the moulding of the architrave, to which division of the entablature they may be said to belong, although evidently a continuation of the ornaments on the frieze. Some suppose them to have been intended to represent nails, others drops of water running down the channels of the triglyphs and settling beneath them; be that as it may, they certainly contribute in no small degree to architectonic expression and effect, inasmuch as they break the monotony of line, and by extending some ornament to the architrave bring it into harmony with the frieze. The space between one triglyph and another being regulated by the height of the frieze, since each interval or metope forms a square, this circumstance also regulates the *intercolumniation*, or distances at which the columns are placed; because as there must be a triglyph over every column, there cannot be more than one triglyph over each intercolumn, unless the latter be increased to the extent of another triglyph and metope; that is, made half as wide again. Consequently there are hardly any instances of more than *monotriglyphic* intercolumniation (that is, with more than a single triglyph over each intercolumn) in Grecian buildings, except when the centre intercolumn is made wider than the others, as in the Propylæa at Athens, where a ditriglyphic arrangement is employed.

Like every other part of the order, the Doric cornice is composed of few and bold parts; it consists of little more than a corona (the projecting and principal member in every cornice), finished above by one or two simple mouldings, and having attached to its soffit a series of shallow plates or tablets, studded with guttæ. These are termed *mutules*, and are the peculiar distinctive marks of the Doric cornice, in like manner as dentils are of the Ionic, and modillions of the Corinthian. They may be considered as being to the cornice what the triglyphs are to the frieze, and there is one corresponding to each metope as well as each triglyph; which produces a beautiful gradation of parts, for as there is an additional triglyph between every column, so is there an additional mutule between every triglyph; whereas, were there no more triglyphs than columns, and no more mutules than triglyphs, the effect would be both monotonous and poor, and these different features would be confined to distinct lines from top to bottom. The average height of the entablature is about two diameters, or one-fourth of the whole order, taking the height of the column at six diameters.

The sloping or *raking cornices* of the pediment resemble the horizontal one, except that there the mutules are omitted. In order, however, to give increased depth and importance to the pediment, as the finish of the whole structure, its cornices have an additional member, termed by some the *epitithedas*, consisting of an ovolo, or convex moulding, or a cymatium; sometimes deeper, sometimes shallower. This *epitithedas* was continued a little way at the angles, where it usually terminated against a block, carved with a lion's head, or some other ornament. The face of the pediment itself, termed the *tympanum* (called by the Greeks ἀετός, ἀέτωμα), was almost always filled with sculpture. The pediment was invariably of a low pitch, but not always of the same pitch; on the contrary, whatever the span might be, its height continued nearly the same, it being more or less acute, in proportion as the portico was narrow or broad: its average height was equal to that of the entablature, and either a little diminished or increased according to circumstances, but hardly ever so much as to render the tympanum deeper than the entablature. The accompanying cut showing the portico of the Doric temple of Athene at Ægina as restored, will illustrate many of the leading characteristics of the Doric style as here pointed out.



Front Elevation of the Temple of Ægina, as restored.

A list of the principal Doric temples is given under COLUMN; as convenient practical examples of this order, where the reader may study its character, and learn to distinguish, in actual buildings, the various members and particulars here pointed out, not, be it remembered, as faithful illustrations of the æsthetic principles of Grecian Doric—we refer to the portico entrance to the North-Western Railway Terminus, Euston Square, and the Corn Market, Mark Lane, in which latter the frieze is decorated with wreaths instead of triglyphs—as in the monument of Thrasyllus at Athens—and consequently the spaces between them cannot be called metopes.

In the *Ionic Order* the column differs widely from that of the Doric, not only in the form of its capital, and in having a base, but in the contour of its shaft and the mode of fluting, it being more slender and not tapering so suddenly. The base is generally that termed the Attic-base, composed of two tori, or convex rings, with a concave moulding, the scotia, between them; for as the Doric character demands plane surfaces and lines, so does the Ionic require curved mouldings and contours, as harmonising with the curved forms of the volutes of the capitals. To prevent the harshness which would result, if the mouldings forming the base jutted out abruptly from the lower end of the shaft, the latter is made to spread itself out immediately above the base in a sweeping curve, termed the apophyge. The number of the flutings of the shaft is increased from twenty to twenty-four; besides which there are spaces left between them (fillets); for the mere arrises or sharp edges, peculiar to the Doric or earliest mode of fluting, would be utterly at variance with the rounded contours of the base and capital. The channels themselves being thus multiplied and set apart from each other, are consequently much narrower than those of the other order, and considerably deeper in proportion to their breadth; and instead of terminating in flattish curves, their extremities are made the half of a circle, or an ellipse: all which circumstances contribute to uniform delicacy of expression. It should be observed, too, that the upper torus of the base was generally fluted horizontally, thereby producing uniformity of decoration between that and the shaft, with contrast as to the mode of applying it. When not so fluted, that torus was sometimes enriched with a *guilloche*, a beautiful sort of chain-like ornament sculptured on its surface: see example in the cut of the base of an Ionic column from the Erechtheium under COLUMN.

The capital may be described generally as consisting of two faces, about as wide, measured across the volutes, as the base—that is, a diameter and a half, or 90 minutes; which breadth is divided into three equal parts (more or less), 30 minutes being allowed for each volute. These volutes are composed of spiral mouldings, which make several revolutions, and gradually become narrower as they approach what is termed the eye or cathetus; in the richer capitals of this class there are intermediate spirals, following the course of the other; the spaces or interspirals, forming slightly concave surfaces (see diagram under COLUMN). In all the Athenian examples there is also a flowing or festoon hem forming the lower edge of the face between the volutes, whose curve harmonises most beautifully with the outline of the volutes themselves; whereas, in the capital of the Asiatic Ionic, as well as the Roman and modern Italian, the volutes are here connected by a straight line. Immediately beneath this part of the capital is a carved convex moulding, to which succeeds the echinus or ovolo (so called because cut into the form of eggs), and lesser mouldings. The idea of an Ionic capital therefore seems to have been that of introducing an ornamental mass between the echinus and abacus of the earlier shaped capital, and rolling up its deep projecting extremities into volutes. Besides the capital (properly so speaking, where additional richness was required, and also increased height for the column, without much increasing that of the shaft), a necking, enriched with sculpture, and separated from the shaft by a carved convex moulding, was introduced. The abacus is square in plan, and its sides form a cyma reversa, or ogee moulding, either carved or plain, according as the capital itself is more or less enriched. But the capital itself, at least that portion of it occupied by the volutes, is not so deep on its sides as on the two faces; the reason for which is obvious, because either those faces must have been much narrower, or if this part formed a perfectly square mass of a diameter and a half, it would overhang the upper parts of the shaft, and project beyond the architrave in a most unsightly manner. The baluster sides of the volutes, as they are termed, are, for the sake of elegance and lightness, hollowed out so as to assume something of the appearance of two tubes or horns, whose broader extremities or mouths come against the back of the volutes. The capitals at the angles of a portico are frequently differently arranged, since, in order to obtain a face on the return similar to that in front, the outer volute is turned diagonally, so as to serve for both faces; a mode adopted for all the capitals, without distinction, by many Italian architects. The architrave is divided into three nearly equal faciæ, projecting very slightly one over the other, and crowned by a cyma recta moulding, carved or plain, as the rest happens to be more or less enriched. The caryatid figures, which in some buildings of this order supply the place of columns, are noticed under CARYATIDES.

The cornice in Athenian examples is exceedingly simple, consisting only of two mouldings beneath the corona, the uppermost being within the hollowed soffit of that member; nor do dentils, which are generally reckoned the distinguishing marks of the Ionic cornice, appear to have been used, except by the Asiatic Greeks. Consequently, unless the frieze be enriched with sculpture, so as along with the cornice to produce a rich ornamental mass above the architrave, not only is the cornice apt to appear meagre, but the whole entablature to look cold and naked, even plainer than that of the Doric order, and to offer anything but a pleasing contrast to the elegant richness of the capitals below it.

What has already been said in regard to the pediment will suffice for this order likewise, there being no other difference than what is occasioned by the cornices themselves. But having thus far explained the two chief Greek orders or styles of columns, in regard to columns and entablatures, we now proceed to notice what in certain situations are employed as adequate to, or substitutes for, columns, namely, *antæ*, or pilasters. In Italian architecture, pilasters are very frequently employed in lieu of columns, or are placed against a wall to correspond with a range of columns in front of it; their bases and capitals, too, are made to correspond with those of the columns, as far as the difference between a square and circular plan will allow. The Greeks, on the contrary, never employed antæ, except at an angle or the extremity of a wall; and instead of aiming at perfect similarity, they purposely gave to such pilasters, bases and antæ-caps, dissimilar from those of the columns; neither did they diminish them, but made them of the same width above and below, which width was determined by that of the soffit of the architrave, and was therefore something less than the lower diameter of the column, but greater than the upper one, since both in the Doric and Ionic the architrave overhangs the upper part of the column. Thus they kept the antæ and columns quite distinct in character, thereby producing variety and contrast without injury to consistency. Sometimes the Doric anta has a simple kind of moulding and groove at its foot, which seems requisite to detach it from the wall, whereas the plain foot of the column resting on the pavement or steps defines itself to the eye quite sufficiently. The Doric anta-cap is very simple, and its abacus and other mouldings much narrower than those of the column-capital.

Although more ornate than those of the Doric, Ionic antæ-caps differ still more than the others do from the capitals of their respective columns, inasmuch as they have nothing whatever answering to those exceedingly characteristic features, the volutes; nevertheless they are so strongly marked by the same style as to render it impossible to mistake them, or attribute them to any other order. Between the bases of the antæ and those of the columns there are very slight differences; the chief is that besides the upper torus being fluted like that to the base of the column, the under one is also enriched, but by reeding or convex mouldings. There is also an additional concave sweep moulding placed beneath the torus. It is further to be observed, that antæ are never fluted, as is generally the case with Roman and Italian pilasters whenever the columns are so, and consequently a stronger distinction is kept up between the antæ and the columns.

In the above sketch of this order we have merely pointed out in a general manner the leading characteristics, without taking notice of the very numerous varieties, since hardly any two examples are perfectly alike, and some are strikingly dissimilar from any other. One of the most remarkable is that of the internal order of the Temple of Apollo at Bassæ, near Phigaleia, in Arcadia. The base, which is altogether different from the Attic one, is of great diameter compared with the shaft, which spreads down to it with a sudden sweep; hardly less peculiar is the style of the fluting, the channels being very broad and shallow, and the fillets very narrow, while the extremities of the channel are hardly curved at all, so that it seems but the first remove from Doric fluting. The capital is still more extraordinary, inasmuch as there are four voluted faces; at least there would be, if the columns were not attached to projecting piers. In order to effect this the faces are made concave, so that the volutes turn out towards the angles, and are placed at only half the usual distance from each other, so as to reduce still more the width of each face, else, as has already been remarked, the capital being square, it would be too bulky for the column. In its detail this capital is so plain that it looks very much like one of the earliest essays at a voluted capital; nor is it improbable that at first the design was to make such capitals perfectly square like the Doric abacus, and to produce four uniform voluted faces.

Under COLUMN will be found a list of the principal Grecian Ionic temples. One of the best modern specimens of Athenian Ionic is the portico of St. Pancras' church, London, by Mr. Inwood, a well-finished copy of one of the most florid specimens of the order, that of the Erechtheium. On the lateral porches at the eastern end he has given an application of caryatides supporting an entablature after the small building called the Pandrosium, attached to one angle of the Erechtheium. Other modern examples of the Ionic order in the metropolis are, the British Museum, the Post Office, the India House, which is more Asiatic Ionic than Athenian; and the portico of the College of Surgeons, Lincoln's-inn-fields.

Corinthian Order.—Though the small structure at Athens, called the Choragic Monument of Lysicrates, furnishes one of the most exquisitely designed examples of the Corinthian or foliaged-capital order that have been preserved to us, it is almost a solitary extant instance of the application of it by the Greeks; since the capitals of the small columns of the Tower of the Winds, have merely a single row of acanthus leaves at bottom. It is true that some magnificent edifices belonging to this order, such as the Temple of Jupiter Olympius at Athens, were erected in Greece; but they belong to a later period, after the order had been extensively employed by the Romans, who must be regarded as having brought it to perfection as a distinct style. That the order was derived in the first instance from Egypt we have already seen; eventually the Greeks added the Ionic volute, and produced a composite order entirely their own. In the Tower of the Winds, at Athens, the height of the column is little more than eight, in the Monument of Lysicrates it is nearly ten, diameters. [COLUMN.] In the former example, as we have seen, there are no volutes, and the upper row of leaves are those of the water lily. But the Lysicrates and later capitals are composed of two rows of acanthus leaves [ACANTHUS], those of the upper row springing up from between the lower ones; and from the sides of the centre-leaf spring out other leaves, whence emerge the helices or spirals, placed diagonally to support the extremities of the abacus, besides lesser spirals which meet, and sometimes intertwine each other above each middle leaf. The abacus itself, which is peculiar to this order, may be described as square in its general plan, but having its sides made somewhat concave, so as to curve out towards the angles, yet not overhang the body of the capital. The Corinthian entablature differs little from that of the Ionic, except in the cornice being made richer and deeper, and the number of its members being increased, in order to harmonise with the deeper capital of the columns. One of the features peculiar to it is the series of modillions or small brackets supporting the corona. We have mentioned the two Athenian examples of this order. In the metropolis most Corinthian capitals are Roman. But an imitation of the Temple of Lysicrates occurs oddly placed on the church of St. Philip, Regent Street, to serve as a belfry; and a careful restoration of it may be seen in the Crystal Palace, at Sydenham.

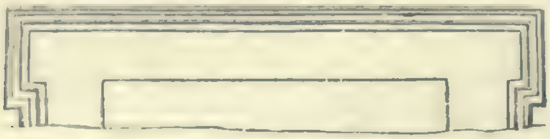
For all that concerns the plans of Grecian temples, their peculiarities of construction, and the terms employed to express their varieties, as designated from the number and position of the columns, we must refer the reader to the articles TEMPLE, and PORTICO; but it will be more convenient here to explain some points in the arrangement of columns, and other matters which are distinctive of Greek architecture.

In regard to *Intercolumniation*, or the distances at which columns are placed from each other, and upon which so much of their effect depends, it has already been mentioned that in the Doric order this is regulated by the triglyphs, and that monotriglyphic intercolumniation may be considered as the extreme of pycnostyle (thickly set), as it will sometimes occasion the columns to be less than a diameter and a half apart, the limits assigned to pycnostyle. But this of course depends upon the proportion which the metopes and triglyphs bear to the lower diameter of the columns. That such very close arrangement should be employed for the most solid of the orders, would almost appear an incongruity; yet it should be observed that in reality this arrangement is not so close as it appears to be when expressed by the proportion which the foot of the column bears to the intercolumn, because the shafts taper so much that what would be an inter-column of less than a diameter and a half below, would be two of the upper diameters, or more, above. The second mode is termed *systyle*, or two diameters apart; the third *eustyle*, or two and a quarter; the fourth *diastyle*, or three diameters; and, lastly, *aræostyle*, or four or more diameters. But the precise spaces thus defined do not seem to have been adhered to; and the Greeks, who appear never to have worked according to fixed rules, although precise rules have been since laid down from their works, seem to have allowed themselves any intermediate interval from a diameter and a quarter to two diameters, which they rarely exceeded, except when particular circumstances required it, and when the columns themselves were so small, that had they not been more than two diameters apart, the intercolumns would have been inconveniently narrow. When the columns are pycnostyle or less than two diameters apart, they produce richness not only by their increased number in a given space, but also owing to their being forcibly relieved by the increased depth of shadow behind them.

So far from employing pedestals to columns, which some have considered as forming as essential a part of an order as the entablature, the Greeks placed their columns immediately on the floor, or uppermost step; the whole temple being generally raised on a low platform, to which the ascent was usually by three deep steps, or gradini, serving as a base to the edifice. The depth of the steps was not accommodated to the human stature, but regulated so as to accord with the dimensions of the column: it has, therefore, been conjectured, that either a sloping platform of wood, or lesser steps of the same material, were employed as the real ascent to the temple. The Greeks invariably placed their columns singly, never in pairs, as has frequently been done by modern architects, and which, if not indefensible, ought never to be resorted to, unless required by positive necessity. Of engaged columns,—that is, columns half or three-quarters of a circle in plan, and placed against a wall as if built into it,—there are so very few instances in Grecian architecture, that they are to be considered merely as exceptions. One such authority for the use of half-columns occurs in the west front of the triple temple, or Erechtheium, at Athens [see plan under ERECHTHEIUM]. In the Italian or Palladian school, they prevail almost to the exclusion of insulated columns. Yet not only is much of the effect of the columns themselves lost, but also that of light and shade. But if something like the authority of the Greeks themselves can be pleaded in support of engaged columns, it cannot be adduced as countenancing a barbarism to which that practice and the employment of wide intercolumns gave rise, namely, that of making a break in the entablature above every column, and thereby destroying the continuous horizontal line of that part of the order, and carrying the vertical ones up into it. Another practice, not observed in any extant Greek building,[*] is that of supercolumniation, or the placing one order upon another, sometimes even to the extent of three or more; the diameter of the columns decreasing, and of course the width of the intercolumns increasing as they ascend. Inigo Jones's building called the Banqueting House, at Whitehall, affords an example of supercolumniation, together with one of engaged columns and broken entablatures.

Although the name itself would seem to show the contrary, Grecian architecture affords no precedent for what is termed an Attic order,—that is, a series of dwarf pilasters crowned by a cornice; and balustrades, also, are of modern invention. [Attic.] The only thing of the kind in ancient examples, and that of exceedingly rare occurrence, is a low and plain unbroken podium, or parapet; that is, without pilasters or other projections, above the cornice of a building. Far from attempting to conceal the roofs of their temples, the Greeks not only made them very conspicuous in the outline of the pediments, but bestowed much decoration on them, ornamenting the ridges and tiles, and placing a series of *antefixæ*, or enriched front tiles, above the cornice along the sides of the building. This species of embellishment has been adopted in the church of St. Pancras, which structure also affords correct specimens of Grecian doors and windows. The latter, which are copied from those of the Temple of Minerva Polias, forming the western portion of the Erechtheium, are almost the sole extant type in Grecian architecture for such apertures. They are surrounded by a moulded architrave, and the jambs incline towards each other, so that the aperture of the window is somewhat narrower at the top than at bottom. This peculiarity may have arisen from the difficulty of procuring single stones for the lintel or upper architrave wide enough to extend over an aperture equal to the sill of the window; yet it may also have been adopted entirely as a matter of taste, with the view of both producing a contrast between the sloping outline of the windows, and the vertical lines of the walls and antæ; and an accordance with the tapering form of the columns. What serves to countenance this last idea is, that we find the same principle observed here as in the column itself, namely, that of restoring at the summit what had been lost by diminution upwards; for as the capital spreads out as wide as the base of the column, so is the upper horizontal lintel made as wide as the sill of the window, by means of a break towards the top of the side architraves (technically called a knee), so that the architrave expands there to the width of the sill.

The doorways of Grecian temples were made lofty and spacious, not only for the sake of rendering them important architectural features, but also because the light was admitted into the cella, or interior fane, usually of small dimensions compared with the general structure, through the entrance. The doorway is often inclined inwards, or contracted at the top; it has also a peculiar lintel or top-stone, with moulding running round it and meeting the ends of the architraves, and forming two elbows, thus:—



Greek lintel head, showing the manner in which the architrave moulding is formed round it.

The mouldings of the architraves are delicately formed, and decorated with ornaments, and a frieze and cornice supported on consoles are sometimes added. The decorations of the Erechtheium doorway are very rich, but the size of our cut precludes the possibility of giving them. This doorway is copied in the central doorway of St. Pancras Church. There was never more than one doorway within the portico or pronaos of a Greek temple. We have no example of the form and construction of a Greek door.

GREEK ARCHITECTURE. [Grecian Architecture.]

GREEK CHURCH. The Greek or Eastern Church is that part of Christendom which, founded, as is said, by St. Mark in Alexandria, about A.D. 60, separated from the Roman or Western Church in the 9th century. Even previously to that epoch there were several dissensions between the patriarchs of Constantinople and the popes of Rome, who claimed a supremacy over all the churches of Christendom; but the decided breach between the two churches dates from the year 862, under the patriarch Photius. The extension of the Greek Church by the conversion of the Bulgarians and some other Sclavonian nations excited the jealousy of the popes, who, moreover, having found a new support in the establishment of the Franko-Roman empire, began to act with more boldness against the emperors of Constantinople. Photius reproached the Western Church with the wanton addition of the word "Filioque" ("and the son") to the words "I believe in the Holy Ghost, the Lord and giver of life, who proceedeth from the Father," contained in the Nicene creed, and which he declared to be an antiscriptural doctrine. He reproached them, also, with having introduced several innovations unknown to the primitive Christian Church; as, for instance, the celibacy of priests, the repetition of the anointment, with the chrisma (confirmation), and the fastings on Saturdays; but he particularly inveighed against the assumption of the Roman bishops in considering themselves as the head of all Christendom, and treating the Greek patriarchs as subordinate to them. The final separation, however, of the Eastern from the Western Church did not take place till 1054, under the patriarch Michael Cerularius, who, in addition to the matters alleged by Photius, attacked the Latins for using unleavened bread at the communion, and for the profligacy of their clergy, &c., for which he was excommunicated by Pope Leo IX. The attempts at uniting the two churches, which were made either by the popes, in order to extend their dominion over the East, or by the emperors of Constantinople, who, being pressed by the Mohammedans, sought assistance from the Western powers, generally failed through the pride and interested motives of the leaders of both the parties. While Roman Catholicism was gradually developing itself under Gregorius VII. and his followers, as well as by the aid of the scholastic philosophy, the Greek Church remained stationary in its organisation as well as in its rules of doctrine, as laid down, 730, by John Damascenus.

The capture of Constantinople by the Latins in 1204, and the oppression of the Greeks during their sway, were calculated to widen the breach between the two churches. Michael II. Palæologos, who expelled the Latins from Constantinople in 1261, was inclined to effect a union with Rome; and his ambassador, with some Greek clergymen devoted to him, acknowledged the supremacy of the pope at the council of Lyon (1274), and to confirm this acknowledgment, a synod was convoked at Constantinople in 1277. But the bulk of the Greek Church being opposed to the measure, and the Pope Martin VI. having excommunicated the Emperor Michael, from political motives (1281), the separation from the Church of Rome was solemnly confirmed by the synods of Constantinople held in 1283 and 1285. The last attempt at uniting the two churches was made by the Emperor John VII. Palæologos, who, being driven to extremity by the Turks, came to Italy, and, at the council of Florence, in 1438, acknowledged the supremacy of the pope. The union was however not accepted either by the Greek clergy or by the people; but the constant efforts of Rome to attain this great object resulted in bringing to her many Greek churches in various parts of the world, and particularly in Hungary and Poland.

The Greek Church, like the Roman Catholic, acknowledges a double foundation of faith—the Bible, and tradition. Under this latter appellation it comprehends such doctrines as are supposed to have been verbally taught by the apostles, and which were confirmed by the Greek fathers of the Church, and by John Damascenus, as well as by the first seven Œcumenic councils of the Church (the 1st and 2nd of Nicæa, the 1st, 2nd, and 3rd of Constantinople, and those of Ephesus and Chalcedon). It forbids the patriarch and the synods to introduce any new dogma, but considers a full belief in those already established as indispensable to salvation. It maintains that the Holy Ghost proceeds only from the Father, differing in that point from the Roman Catholic church, as well as from all Protestant churches, which admit the proceeding of the Holy Ghost from the Father and the Son ("Filioque"). Like the Roman Catholic church, it admits seven sacraments: baptism; the chrisma; the communion, preceded by auricular confession; penitence; priesthood; matrimony; and extreme unction. But it differs from the Western church in the following points: 1. That baptism, in order entirely to remove original sin, should be performed by immersion of the body three times in water; and that the chrisma, which it considers as the completion of baptism, should be administered at the same time. 2. Although it admits the doctrine of transubstantiation, it prescribes the communion of two kinds, which is administered with leavened bread; and the wine, which is mixed with water, is not given from the cup as among the Protestants, but put by the priest with a small spoon into the mouth of the communicant. 3. It requires from the secular clergy, as a necessary condition for receiving ordination, marriage with a virgin; but a priest who loses his wife cannot marry again, nor can a person be ordained priest who has been married more than once, or who has married a widow. It allows laymen to contract marriage only three times, and is very strict in regard to degrees of consanguinity; and it also establishes, in addition to the connection by blood, a spiritual affinity between sponsor and god-child. 4. It admits no purgatory. Besides the above-mentioned important points, the Greek differs from the Roman Church in several other matters of small moment. Thus, for instance, it allows the anointing of the body with the chrisma, not only to persons threatened with death, but to all sick persons as a means for restoring their health and obtaining the pardon of their sins. Although it admits no purgatory, it is customary with many of its followers to give the deceased a written testimony from the priest of his religious conduct, in order thereby to facilitate his entrance into paradise. This, however, is evidently a custom transmitted from the ancient Greeks, and it must be considered as a practice rather connived at than prescribed by the Greek Church. The same Church admits no works of supererogation, neither does it acknowledge any vicar of Christ like the Pope of Rome. Having retained the Decalogue unmutilated, it forbids, conformably to the second commandment, all kinds of carved images; but it permits and encourages paintings representing the Deity, the Holy Virgin, and saints.

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[*] The temple of Athena Alea, at Tegea, built about 383, B.C., by Scopas, had, in the interior, a Corinthian (κόσμος Κορίνθιος) imposed upon a Doric order. The exterior columns were Ionic. (Pausan., 'Arcad.,' c. 45.) In this passage the word κόσμος (kosmos) corresponds to the modern word Order.

The followers of the Eastern Church are no less zealous than the Roman Catholics in invoking saints, particularly the Holy Virgin, and in their veneration of relics. Their fasts are much more numerous and strict than those of the Roman Catholics. Besides Wednesday and Friday in every week, they have four great fasts in the year: Lent, or the fast of 40 days before Easter; another fast which lasts from Trinity day to the feast of St. Peter and Paul, 29th of June; a third, "to the mother of God," which continues from the 1st to the 15th of August; and a fourth beginning at St. Philip's day, on the 15th of November, and ending at Christmas.

During all this time they abstain not only from meat, but also from milk, butter, and eggs. The ritual of the Greek Church consists almost entirely of outward ceremonies, and preaching or religious instruction is scarcely ever used. In addition to the mass, which forms the most important part, the liturgy consists in reading several passages of the Scriptures and a repetition of creeds and prayers, which the officiating priest begins and which are responded by the congregation. Every congregation has a choir which sings psalms and hymns, but the congregation takes no part in them. Instrumental music is entirely excluded from divine service.

The Greek convents follow the strict rule of St. Basilius. The abbot of a Greek convent is called Hegumenos, and the abbess Hegumena; the abbots who superintend several convents have the title of Archimandrite, and rank next to bishops. All the high ecclesiastical dignities, as bishops, archbishops, and metropolitans, are chosen from the regular clergy; while the secular can rise only to the rank of Protopapas, which is only one degree higher than that of an ordinary priest.

The Greek Church under the Turkish dominion preserves almost entirely its ancient organisation. It is now governed by the patriarchs of Constantinople, Alexandria, Antioch, and Jerusalem, of whom the first, as the Œcumenic patriarch, presides over the general synods of Constantinople, which are composed of the above-mentioned patriarchs, several metropolitans and bishops, as well as twelve eminent Greek laymen. He exercises a supreme ecclesiastical authority over all the Greeks of the Ottoman empire, and is also acknowledged as the primate of their Church by the inhabitants of the Ionian Islands, and such of those under the dominion of Austria, who profess the Greek religion; but, except by confirming the appointment of bishops when elected by the clergy, and presiding at councils, he exercises no supremacy over the other patriarchs. Independent states professing the religion of the Greek church have almost uniformly their own ecclesiastical superior, as was the case with Georgia, Abkhasia, and Servia. In Russia, since the time of Peter the Great, the sovereign is the real head of the Church, and the patriarchal powers are exercised by a synod. In Greece a similar constitution has been adopted (it was only recognised after much negotiation by the patriarch of Constantinople in 1850); and now the archbishop of Athens is at the head of the national synod.

For an account of the festivals, ceremonies, liturgies, &c., see 'History of the Eastern Church,' by the Rev. John Mason Neale, M.A.

GREEK MUSIC. [Music, History of.]

GREEN. [Light.]

GREENHOUSE. A building in which small plants of a delicate or exotic character are raised, without being exposed to the variations or inclemencies of the atmosphere. The temperature must be regulated by the nature of the plants, and it may be obtained by the use of stoves, of hot air, or of hot-water pipes, or in the case of conservatories by surrounding the earth of the pit by manure, whose gradual combustion, in the process of decomposition, may give out the necessary quantity of warmth.

It is usual, in the construction of greenhouses, to make three of the vertical sides of glass, and to hang the frames so as to allow air to be admitted at will. The top is also made of glass, and partially moveable. Care must be taken to conduct the waters of condensation in such a manner as not to allow them to drip upon the plants; and all passage of moisture, through the capillary action of the ground, must be intercepted. As a rule, the opaque side, or wall, of a greenhouse should be towards the north.

GREEN VITRIOL. [Iron, *Protosulphate of.*]

GREENWICH OBSERVATORY. [Observatories.]

GREGORIAN KALENDAR. [Kalendar.]

GRENADE, properly called hand-grenade, is a shell or hollow ball of iron, 2½ inches in diameter, and about 3 lbs. in weight, which, being charged with powder and provided with a fuse, is thrown by the hand from the parapets into the ditch and covered-way when occupied by the besiegers; or from the covered-way into the trenches, when the latter approach within 25 yards of the crest of the glacis. Hand-grenades are especially useful in the defence of unflanked ditches, &c.

As soon as the composition in the fuse is consumed, the fire communicates with the powder, and the ball is burst in fragments.

Grenades were first used in 1594.

Grenades have been made of glass, either with a fuse, or with four or five nipples distributed over the surface of the grenade. Percussion caps are placed on these nipples, which are exploded by the blow of the shell falling on the ground, and cause the ignition of the charge.

GRENADIERS are the tallest and strongest men of a battalion; they are embodied in one company, which is disposed at the head of the battalion when in column, and on the right flank when in line.

In France, as early as the year 1667, four men, appointed during a siege to throw grenades into the covered way of a fortress, and to take the lead in an assault, were distributed in each company of that which was called the king's regiment (infantry); and three years afterwards these men were formed into a separate company: subsequently every regiment in the French service had a company or two companies of grenadiers, and the regiment of guards had three: they were considered as the *élite* of the soldiery, being men of tried steadiness and valour. In 1676, the king of France instituted a company of cavalry designated horse-grenadiers, whose duty it was to repair roads previously to a march of the household troops.

It is probable that men under the denomination of grenadiers formed part of an English army soon after the introduction of that class of soldiers into the French service; for, from a list of the commissioned officers of the army in 1684, it appears that most of the regiments had grenadier companies. A corps of grenadiers was also attached to each of the three troops of horse-guards; in 1693 these were formed into a troop, and in 1702 another troop was added.

The English foot-grenadiers were at first probably employed in duties similar to those of the corresponding troops in the French service: for, in a work on the English military discipline (1686), they are said to be provided with muskets, swords, pouches to carry grenades, and hatchets: with these last, after firing and throwing their grenades, they were to cut down obstacles in order to enable the troops to rush on the enemy.

The men in the first of the three regiments of foot-guards are now designated "Grenadier Guards," and the Scots Greys constitute a regiment of horse-grenadiers; in both of those regiments a high bearskin cap is worn: but the men forming the grenadier companies of regiments of the line wear the same kind of caps, and, except slight peculiarities in the ornaments of the coat and hat, they are clothed and armed like other infantry soldiers.

GROOM, in old English, meant a servant in some mean station, a lad or lacquey who was sent on errands: and is said, by Kilian, to be derived from the Flemish *grom*, a boy. It answered to the French *garçon*, or perhaps *gamin*. At present, in common life, groom means a servant especially attendant on the stable. Jamieson says the original word was *gom*, and that the letter *r* has been inserted only in English and Scotch. The German *brautigam* is the English bridegroom.

In higher life, groom is the denomination of several officers or servants of the royal household, mostly in the lord chamberlain's department: such as grooms in waiting, grooms of the great chamber, grooms of the privy chamber, groom of the robes or stole, and, in the lord steward's department, groom of the almonry.

There was formerly also, in the lord steward's department, a *groom-porter*, who is said to have succeeded to the office of master of the revels, then disused. His business was to see the king's lodging furnished with tables, chairs, stools, and firing; as also to provide cards, dice, &c., and to decide disputes arising at cards, dice, bowling, &c.

From allusions in some of Ben Jonson's and Chapman's plays, it appears that the groom-porter was formerly allowed to keep an open gambling-table at Christmas: it is mentioned as still existing in one of Lady Mary Wortley Montagu's eclogues:—

> "At the *groom-porter's* batter'd bullies play."
> *Thursday*, *Ecl.* 4, Dodsley's *Collect.*, i. 107.

This abuse was removed in the reign of George III. Bray, in his account of the Lord of Misrule, in the 'Archæologia,' vol. xviii., p. 317, says, George I. and II. played hazard in public on certain days, attended by the groom-porter. The appellation, however, is still kept up: the names of three groom-porters occur among the inferior servants in the present enumeration of Her Majesty's household.

GROUND-BASE, in music, a subject consisting of very few bars, adopted as a base, and continually repeated during the whole movement, while the upper part, or parts, proceed at liberty. That the composers of the 17th century were proud of displaying their patience and industry by writing on subjects of this kind, we have many proofs remaining, one whereof, a chaconne by Purcell, which is equally good as an example and as a composition, is given in Dr. Crotch's 'Specimens,' vol. ii. p. 91.

GROUND GRU. [Ice.]

GROUND TACKLE comprises anchor, cable, bitts, stoppers, windlass, and all the articles and appliances used in securing a ship at anchor.

Enough for our purpose has been said of the anchor under its proper head [Anchor], to which we refer.

That the whole subject claims attention, and is worthy of anxious investigation, may not only be gathered from a consideration of the disasters which have so lately strewn our coasts with wreck (too many of these wrecks arising from defects in ground tackle), but parliament has just received favourably the application from Sir J. Elphinstone for a select committee "to inquire into the manufacture of anchors and chain cables for the merchant service," and the motion was agreed to on the 2nd of February, 1860.

The writer remembers the time when the chain cable had not supplanted that of hemp. In those days, not half a century distant, the East Indiaman, the deeply-laden West Indiaman, the burdensome collier, and even the line-of-battle ship, were seen in that far-famed and dreaded roadstead, "the Downs," on the Kentish coast, plunging to the strain of a long scope of hempen and "coir" cables, driving onwards again through surge and surf to the point of mean tension, from which a huge sea occasionally hurled them; the *elasticity* of the cables acting like a spring against the sudden blow from a huge wave sufficient to sweep the decks and cause the ship to tremble. It is well to contrast this with the present system. At the time when the chain cable was merely an attractive experiment, the oldest pilots and seamen were of opinion that its rigidity would in bad weather tear the bows from a ship, even from the strongest. For years it was remarkable that until ships were strengthened for the purpose, the capsizing of the windlass [WINDLASS] was a circumstance of more frequent occurrence; and it was only when public attention was drawn by chain makers to the fact, that the weight of the submerged chain itself, hanging in a curve, in some measure modified the shock of a sudden tension, that the ship-owners consented to fit their ships with a certainly more compact and more manageable cable, such as we have in use at the present day. The liability of the old cables to be destroyed by chafing in rocky anchorage grounds, frequently occasioned the loss of shipping. The necessity of anchoring in such unfavourable places might occur several times in the course of a long voyage, and not only would danger be incurred on each occasion, but there was the risk of a ship being compelled, owing to the loss of anchors, to pursue her course destitute of the usual means of security. The action of the water upon hemp, and its being alternately exposed to the air and water, rendered in time the strongest cables rotten and insecure. The idea of substituting iron cables first occurred to M. Bougainville, who made a voyage round the world, an account of which was published in 1771. The idea was not taken up until 1808, when Mr. Slater, a surgeon in the navy, took out a patent for a chain-cable. Its merits were not much valued until Capt. Brown, who had made experiments with chain-cables which enabled him to form a just opinion of their advantages, published the results, and thus directed the attention of naval men to their superiority. The Admiralty soon after ordered them to be tried in the navy. In 1812, Mr. Brunton obtained a patent for further improvements; and after the war he enjoyed a *brevet* for importing chain-cables into France, but the advantages which he derived from it were so small that he relinquished his privilege.

Chain-cables are now furnished with bolts at the distance of 10 or 15 fathoms from each other, by withdrawing which a ship may slip her anchor in case of necessity with less trouble than was formerly required in cutting a strong hempen cable.

Chain-cables are of various kinds, but one general description of the mode of manufacture will suffice. The efficiency of a cable is dependent on two operations widely distinct, namely, the *forging* and the *testing*. For large chains a piece of iron bar, seldom larger than 2¼ inches diameter, is cut to the proper length for a link, and is shaped in cutting like *fig.* 1. It is also during the cutting, and by means of a powerful revolving disc, bent into the form *fig.* 2. It is then ready for the chain-smith, who is necessarily a well-skilled workman, who carefully welds the two ends together, introducing at the time the cast-iron stud, *fig.* 3, the complete link having the form in *fig.* 4; other links are shut on to this in the same manner, until the ponderous chain, often of about 12 tons weight, is ready for the next process,—that of testing. The perfect welding of the two ends of the bar, is by all respectable anchor-smiths made a subject of pecuniary interest to the workmen themselves, since a failure in a link under testing involves to them loss of time and expense in replacement.

1

2

3

4

5

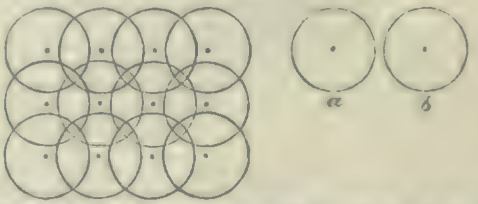
Small vessels use a chain without a stud, the links are variously proportioned to the thickness of the bar, the "short link" having the appearance of *fig.* 5.

From the great care bestowed on the manufacture of chain-cables by such houses as Wood & Co., of Saltney, the Tyne Works, and others eminent in the trade, it is doubtful if much improvement herein can be consistently hoped for. Such firms having their own testing-houses, usually give a certificate with their best chains; but the question arises as to *how far a second testing by public machines, such as at Liverpool, Sunderland, &c., is judicious?*

Professor Hodgkinson gives the tensile strength of wrought-iron as 24 tons to the square inch of section. Now the sectional are of a 2¼ inch chain will be 3·98 square inches, and therefore the maximum of breaking strain which such a chain is calculated to bear is about 95½ tons. But the question was strongly urged by Mr. Saxby in 1855 (see 'Nautical Mag.'), whether the amount of proof required by the government were not the cause of frequent failure of a chain from *over testing.* It is significant that Sir J. Elphinstone has just stated in the House of Commons, that in the public testing machines at Liverpool 82 *per cent.* of the chain-cables tried there had broken!

A few considerations on the operation of testing a metal may be useful. Especially should we investigate the probable effect of testing on the atoms [ATOMS] of which the iron (or metal) is composed. If we view the subject as a mere case of *strain* and *resistance*, we confine our scrutiny to a dangerous limit. Let us suppose it possible that the following figure represents a minute portion of a substance, say of wood or iron:—

Fig. 6.



Imagine the dots to be atoms enormously magnified. It is supposed that in all solids atoms are in approximation only, not in contact; that equilibrium is produced among these atoms by innate counteracting forces, attractive and repulsive. Let the circles surrounding the dots represent the limit of attraction for each atom while in equilibrium: suppose, for example, such dots are the atoms of a lancewood bow. If we cast arrows from it during, say, an hour, we shall on unstringing it find that if the arrows have been projected by means of *sudden jerks*, the bow will sooner recover its original shape than if such arrows had been thrown by a *slowly drawn* force; and moreover we shall find that the arrows in the former case will reach a more distant object than in the latter: hence we infer that the bow will bear a much greater strain with impunity in the first case than in the second. And thus it is with the testing of a chain-cable by the slow method in use. But to return to the bow; the common phrase "*losing its elasticity*" is very significant when applied to iron, which in this respect differs from wood, the one being ductile, the other not; hence a piece of wood bent so much as to draw its atoms farther apart than the imaginary circles in *fig.* 6 permit, or to separate its atoms beyond the sphere of each other's attraction, as shown at *a*, *b*, in *fig.* 6, becomes "broken," *unless* a restoration of position so sudden as to retard the re-arrangement which the disturbance of electric, or galvanic, or calorific agencies induce, *is possible*; and in the case of wrought-iron, this re-arrangement is supposed to commence when the tension amounts to about ten tons to the square inch of sectional area; and this can only take place at the cost of the metal's so-called "elasticity;" such changes in the iron depending upon a supposed polarity imparted to its atoms, by disturbance of electric currents made evident by the production of sensible magnetism.

The iron thus becomes comparatively "brittle," and consequently less able to resist even the proof-strain which, in the first instance, it may have borne with safety.

Does it not appear then that an iron chain cable, in being subjected to a *second* test, must become materially weakened? It is remarkable that, although we speak of iron becoming "permanently" stretched by a strain of upwards of 10 tons, such is merely *conditional*, because the judicious application of a red heat has, in the well-known process of *annealing*, the effect of restoring a state of equilibrium, a *fact bearing strongly upon a consideration of the very nature of electricity itself.* That the greatest strain which affects a ship's cable is in some measure favourable to the "restoration in position" of the molecules of the iron, may be understood from the following unexaggerated sketch. It is not the riding of a ship in a mere tide-way that usually tries a cable to the utmost; but it is the tremendous sudden jerks which a cable sustains when (as in *fig.* 7, c.) a ship is checked by her ground-tackle when on the very crest of a wave. The moment the wave has passed, the weight and "elasticity" of the chain (*if not destroyed by over-testing*), together with the weight of the metal in suspension from the shock, gives the ship an onward impulse which lessens the shock of the next wave (sailors believe in what they call "master-waves"); thus the chain has time to partially recover its atomic equilibrium: this may be seen in the altered angle at which the cable hangs from the hawse, as shown in *fig.* 7 *d.*

It would seem from the above remarks that, to lessen the dangers which at present affect ground tackle, so far as they result from the breaking (or "parting," as it is called) of the chain cable, the following points demand the deepest consideration:—

1. *Is it correct to test a chain to an amount far beyond* 10 *tons to the inch sectional area?*

2. *Should a chain ever be tested a second time?*

3. *Would not a suddenly acting test be preferable to a prolonged tension, at present sustained often for upwards of a quarter of an hour?*

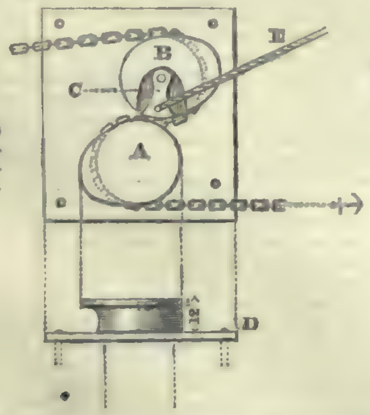
Fig. 7.

4. *Might not a chain after testing be annealed with advantage?*
5. Are chains of present dimensions strong enough?

But the subject of ground-tackle has other important phases. Question 5 suggests that there are times when a chain of sufficient strength to meet an emergency would be far beyond all limits of ordinary requirement, surpassing even the exigency figured above. For many ships are lost on a lèe shore, not so much from fairly riding when at anchor, but from the *shock felt in "bringing up"* on first letting go the anchor. Is it reasonable to suppose that a chain-cable manufactured with every possible care to bear a strain of (say) 95 tons, could resist the violent and sudden shock of a mass like a line-of-battle ship of 120 guns, absolutely weighing above 4000 tons, and *in a state of motion*, perhaps driving at the rate of 6 or 7 miles an hour, or upwards of 10 feet in a second?

We naturally, from this view of matters, turn to look in-board, in order to scrutinise the means used in *checking* a cable under such circumstances. *But there are none*—positively none! The cable is secured by turns round solid blocks of wood of huge scantling, or iron, and which are firmly attached to the framing of the ship itself. It may be supposed that *veering*, or letting go more chain, is the remedy, but it has its dangers also: for if once the chain resist the means of checking its progress, it rushes with increasing force until, from the ship acquiring velocity sternward, it is again suddenly checked by the clench of the cable round the foot of the mast, and like packthread it parts, to the most probable destruction of the ship. Another anchor may immediately be let go, but its chain too probably shares the same fate.

Fig. 8.

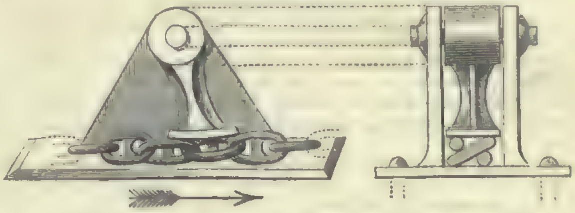


The stopper is shown as it appears while nipping the chain.

Stopper lanyard for securing chain.

A simple remedy has been proposed, and is at least worthy of consideration. If A and B (in *fig.* 8) be two well-secured bitt-heads (they need not be higher than 1 foot or 15 inches above the deck, as seen at D); the cable as brought in from the hawse-pipe passing round A, and also round B with a contrary flexure, would, from the friction exerted in letting go the anchor, be very much retarded. It is true that an extraordinary strain might, in this case also, cause the cable to *rush* out with violence; but if, in addition, there be inserted at C a patent excentric stopper, such as is figured above (and which has been in use for five years in some of the largest ships), the moment the officer of the deck might see fit he might cause to let go the lanyard, E, of the stopper, and allow the friction of the chain along the face of the purposely-lashed-open stopper *itself to close and nip the chain effectually*, gradually or not as he might please. The nature of this stopper admits of its being readily opened to veer away: indeed nothing yet known is likely to be so efficacious. [Windlass.] The stopper referred to is also peculiarly adapted for a position "chock-forward" near the hawse-pipe, for one placed there would prevent the fatal accidents which frequently happen from a capstan "running back" while weighing an anchor, in consequence of a sudden strain coming upon the cable. The stopper admits a chain or rope to pass through it in the direction of the arrow, but if the chain slip back it is immediately nipped by the excentric; and with a great improvement on every other method, inasmuch as it will be seen in *fig.* 9 the *curve rests on three links* of the chain, all others rest on one; and again in other stoppers a rushing chain can never be restrained *with certainty*, for in them, unless the link fall accurately into the "slot" prepared for it, it runs on, and even a *turn* in the chain itself may cause this.

Fig. 9.



(One side is removed to show the action upon the chain.)

It is to Captain Thomas Brown, of the merchant navy, that we owe great improvements, so far as they go; but until some such additions as above suggested are made to existing means for working ground-tackle, the gales upon our coasts will yearly diminish the profits of the shipowner and underwriter, and hundreds of lives will be lost in the most frightful of all calamities, the total shipwreck.

GROWING CROPS. [Emblements.]

GROYNE, a timber estacade, or masonry bank, carried out from the shore of a coast exposed to the action of a littoral current, for the purpose of arresting, as far as possible, the onward progress of the shingle transported by the current. If, indeed, the shingle were allowed to advance without impediment, it would itself, by the abrasion it would produce on the coast line, assist the encroachment of the sea; but the good effect of a series of groynes depends almost entirely upon their being placed so closely to one another that no counter eddy can be formed on the opposite side to the advance of the current.

Groynes are largely used upon the chalk shores of the British Channel, and upon the more yielding strata of the German Ocean. [Sea Defences.]

GRUS, the Crane, a constellation of the southern hemisphere, introduced by Bayer. It is situated between Eridanus and Sagittarius, a little below Piscis Australis. There are no stars of conspicuous brightness in this constellation.

GRUYERE. [Cheese.]

GUAIACENE. [Guaiacyl.]

GUAIACIC ACID. [Guaiacyl.]

GUAIACUM OFFICINA'LE, a tree, native of the West Indies, of which the wood and resin only are used in Britain, but the bark also on the continent, in medicine. The wood should be procured from the duramen, or central part of the trunk, as being the richest in the active principle. This wood should be very dense, heavier than water, of an obscure greenish fawn colour: but the recent fracture is yellowish, exhibiting an unequal cleavage, with a fatty shining appearance, if the specimen be good. The wood of the circumference is lighter, both in colour and weight, pale fawn, and opaque. In Guiana the wood of the *Dépterix odorata* (Tonka bean) is used under the name of guaiac-wood, which it greatly resembles; hence probably the statement of some writers, that the guaiac-tree is a native of America.

Genuine guaiac-wood is destitute of smell, but if rubbed, and still more if set on fire, it evolves an agreeable aromatic odour. If long chewed, the taste is peculiar, guttural, and bitterish. Trommsdorf obtained from 100 parts 26 parts of resin of guaiac: one pound gives two ounces of extract. The active principles are the resin and a peculiar extractive. Guaiac-wood is used in the form of raspings (chiefly obtained from the shops of turners who make blocks for ships of the lignum vitæ, as they term this wood); but this is a mixture of the wood of the external and of the internal layers, of variable strength and quality. The wood is less used than the resin. Guaiac-resin exudes spontaneously, or in consequence of incisions, and hardens on the bark. Resin obtained in this way is generally in spherical or long tear-shaped pieces. It is also procured more abundantly by cutting the stem in pieces of moderate length, boring a hole through it, then putting the one end in the fire, and collecting the resin, which flows from the opposite end, in calabashes. Another mode is to boil splints of the wood in salt and water: also, by digesting the rasped wood and bark in alcohol.

There are some slight differences in colour, transparency, and other points, according to the method of obtaining it; but these are of little consequence, provided no accidental or fraudulent admixture of other substances have occurred, such as pieces of wood and bark, sand, or amber. To purify it from these, it is commonly dissolved in proof spirit. By this means a larger quantity of resin is procured than was originally subjected to the solvent, owing to a hydrate being formed. Resin which has been so purified has lost nearly all acrimony; the resin is likewise adulterated with colophony; and it is said to be adulterated with the resin or gum of the manchineel-tree, a most culpable substitution, owing to its formidable powers.

According to Unverdorben, guaiac-resin consists of two distinct resins: the one is easily soluble in aqua ammoniæ, which the alcoholic solution of acetate of copper precipitates; the other forms with ammonia a tarry combination, which is soluble in six thousand parts of water, and which the alcoholic solution of acetate of copper does not precipitate.

The resin of guaiac becomes blue by continued exposure to the air, and also when in contact with many organic substances: many vegetable substances, particularly several containing gum and starch, turn the tincture of guaiac blue; a point of importance, from the similar effect of iodine on starchy substances.

The acrid taste of guaiac-resin is owing to a peculiar bitter acrid, so-called extractive (or *guaiacin*), which is contained in much greater quantity in the bark than the wood. It is to this principle, according to Buchner, that guaiac-resin is indebted for its medicinal powers.

Guaiac possesses the property of stimulating the system generally, causing increased vascular action, augmented heat of the body, and promotes the secretions of the skin and lungs; but in large doses it produces nausea, anxiety, abdominal pains, and stupor. It is not prized now so highly as on its introduction into European practice in the 16th century, when it bore a most extravagant price, four ducats being often given for a pound of the wood. It is, however, a useful agent in certain forms and stages of gout and rheumatism, and in some cutaneous diseases, especially when in the first set of disorders it is combined with ammonia, and in the latter with mercurials and diaphoretics or antimonials, as in Plummer's pills.

Its insolubility in watery menstrua is an obstacle to its easy administration, and even its alcoholic solutions are precipitated on the addition of water. It is generally made into an emulsion, or given in pills; but a soap may be formed by means of heated aqua potassæ, in which the resin is to be dissolved, then evaporated, and a soft consistent mass is obtained, which may be formed into pills or a bolus.

GUAIACYL ($C_{14}H_7O_4$), the theoretical base of the resin called guaiacum. If this resin is distilled, an oily liquid is obtained, which is regarded as a hydride of guaiacyl, $C_{14}H_7O_4+H$, although it has been named *pyroguaiacic acid.*

Another constituent of guaiacum resin is *guaiacic acid* ($C_{12}H_8O_6$), which crystallises in needles, and is freely soluble in water. By destructive distillation the resin also yields *guaiacene* ($C_{10}H_8O_2$), a light volatile oil, which absorbs oxygen from the air, and forms a crystalline compound.

GUANINE ($C_{10}N_5H_5O_2$), a compound discovered by Unger in guano. It resembles urea in its properties, forming crystallisable salts with hydrochloric, sulphuric, and nitric acids. It is a white powder, and insoluble in water. Its salts are all neutral or acid, none basic.

GUANO (from the Peruvian word *huanu,* which signifies dung) is the excrement of sea-fowl, and was used as a manure probably for ages before Peru was visited by the Spaniards. It is spoken of by Herrera in a work published at Madrid in 1601; by Garcilaso de la Vega, in his 'Memoriales Reales,' published at Lisbon in 1609; and by Ulloa in his 'Voyage.' Garcilaso de la Vega says that "in the time of the Incas there was so much vigilance in guarding these birds (the sea-fowl), that during the rearing season no person was allowed to visit the islands which they frequented, under pain of death, in order that they might not be frightened and driven away from their nests. Neither was it allowed to kill them at any time, either on or off the islands, under the same penalty. Each district or territory had a portion of these islands allotted to it." Mr. Thairlwall, of Richmond, Yorkshire, who has visited the western coast of South America, describes a small island, about three miles in circumference, in 13° 44′ S. lat., on which guano is deposited in a solid mass 200 feet in depth. The surface is coated over with a thick incrustation of almost pure muriate of ammonia; and when the bulk is disturbed, the ammonia given out is so strong as to affect respiration, and to cause an unpleasant sensation in the eyes. Peruvian guano is imported into England only by the agents of the Peruvian government, Messrs. A. Gibbs & Co. About the commencement of 1843 guano was discovered on the island of Ichaboe, about two miles and a half from the mainland of Africa, in 26° 13′ S. lat. and 14° 15′ E. long. The place soon attracted notice, and by the end of 1844 the whole of the guano had been carried away. As many as 350 ships have been anchored off the island at the same time. The guano was 35 to 38 feet in depth, and the deposit extended to a length of about 1100 feet, with an average width of 400 feet. Towards the close of 1844 another guano island (Malagas) was discovered at the entrance of Saldanha Bay. The guano covers an extent of about eight miles, and gradually increases in thickness from about 4 yards to 8 yards. It is obtained for shipment by a licence from the collector of customs at Cape Town. In October, 1845, a cargo of guano was brought to this country from Patagonia. It has been supposed that the excrement of the sea-fowl which swarm on some parts of the coast of Great Britain might be used as a fertiliser with the same results as Peruvian or African guano; but the quantity which could be collected is comparatively small, as the annual accumulation is in most cases washed away by the rains, and the valuable properties of that which remains are dissipated by the changeable nature of our climate. In South America and Africa the dryness of the climate allows the guano deposits of successive years to accumulate, and the heat of the sun produces a coating of the surface which preserves its virtue as a manure. The superiority of the Peruvian over the African and other guanos is owing chiefly to the greater dryness of the climate.

A guano has been found on the Koorya Moorya Islands off the southern coast of Arabia, and has been imported to some extent, but its composition is very inferior to that of the Peruvian in all that constitutes worth in a manure.

The value of guano is to be estimated according to the proportions which it contains of—1, ammonia; 2, phosphates; 3, organic matter. The results of a number of analyses of Peruvian and African guano show the following variations in their composition:—

	Peruvian.	African.
Water	12 to 15	25 to 30
Organic matter	50 to 60	25 to 30
containing	12 to 15 parts of ammonia	5 to 9 parts of ammonia
Phosphate of lime	15 to 25	25 to 30
Fixed salts	—	8 to 10

African guano had the largest proportion of soluble matter, and that from Peru is remarkable for the quantity of uric acid that it contains, an element which dissolves very slowly. African guano may therefore have acted with greater rapidity, but the effect of Peruvian is felt for a long period.

Good Peruvian guano sells now at 13*l.* per ton. The article is extensively adulterated, and instances have occurred in which the adulterated matter prevailed to the extent of 97 per cent. Umber, stone ground into a fine powder, various earths, old mortar, and partially decomposed saw-dust, are employed for this purpose. The mixture is moistened with putrid urine and re-dried. Even genuine guano differs so frequently in quality, that it is never advisable to purchase it without a satisfactory analysis. Purchasers are often deluded with false analyses, and those who deal only with those who profess to be importers are not always safe. Dr. Ure advises the farmer before he buys to obtain an analysis from a competent chemist, and then to cork up a sample in a bottle, and in the event of his crops disappointing reasonable expectation he is in a better position for obtaining satisfaction for any fraud which may have been practised upon him. Farmers' clubs might retain a respectable chemist at a salary on condition that he should perform analyses for the members at a moderate fee. This is what in effect was done by the Agricultural Chemistry Association of Scotland, and the consequence was that scarcely a single sample of adulterated guano was offered for sale in that country.

The easiest test of the purity of guano is its weight. It may vary from 69 to 73 lbs. a bushel, and the lighter the better, provided on throwing it into water some of it floats. If heavier than 73 lbs. per bushel, it has been adulterated with earth. The following are the common chemical tests of its genuineness, as given by Mr. Nesbitt:—

(1). Procure from any druggist a common wide-mouthed 6-oz. bottle, with a *solid* glass stopper. Let this bottle be filled with ordinary water, the stopper inserted, and the exterior well dried. The scales to be used ought to turn well with a couple of grains. In one pan of the scales place the bottle, and exactly counterpoise it in the other by shot, sand, or gravel. Remove the bottle from the scale, pour out two-thirds of the water, and put in 4 oz. avoirdupois of the guano to be tested. Agitate the bottle, adding now and then a little more water; let it rest a couple of minutes, and fill with water so that all the froth escapes from the bottle. Insert the stopper carefully, wipe dry, and place the bottle in the same scale from which it was taken. Add now to the counterpoised scale 1½ oz. avoirdupois and a fourpenny piece; and if the bottle prove the heavier, the guano is in all probability adulterated. (2.) Place 10 grains of the guano in a platinum capsule, which is held by the tongs in the flame of a spirit lamp for several minutes, until the greater part of the organic matter is burnt away. It is allowed to cool for a short time, and a few drops of a strong solution of nitrate of ammonia is added, to assist in consuming the carbon in the residue. The capsule is again gently heated (taking care to prevent its boiling over or losing any of the ash), until the moisture is quite evaporated. A full red heat must then be given it, when, if the guano be pure, the ash will be pearly white, and will not exceed 3½ grains in weight. If adulterated with sand, marl, &c., the ash will always be coloured, and will weigh more than 3½ grains. (3). Dissolve in a quart of water as much common salt as it will take up, and strain the solution. Pour a quantity of it into a saucer or basin, and sprinkle on the surface the guano to be tested. Good guano sinks almost immediately, leaving only a very slight scum. The adulterated leaves the light materials floating on the water. (4.) If chalk or ground limestone has been used in adulterating guano, it may be shown by pouring strong vinegar over a tea-spoonful of the sample placed in a wine-glass. On stirring, effervescence shows its presence. Genuine guano, under the same circumstances, merely allows the escape of a few air bubbles. We add here the method suggested by Dr. Cameron in his recently published lecture on agricultural chemistry, for the detection of spurious guano. By drying and burning, Peruvian guano should lose from 55 to 60 per cent. of its weight. Its ash should be white, and should dissolve readily, and without effervescence, in dilute muriatic acid, leaving insoluble residue, which should not amount to more than 2 per cent. of the weight of the guano. Mixed with quicklime it should give a strong ammoniacal odour. A bushel of guano if pure weighs almost exactly 70 lbs.; if adulterated with clay, marl, sand, &c., the weight will be materially increased, and so far as this test applies gross adulterations will be easily detected.

The great cost of guano has materially checked its consumption, and it will be seen from the following table how much during the past year its consumption has fallen off. The fact is, that at the price of 13*l.* per ton many other manures are cheaper.

The following is a table of the imports since its first introduction :—

Years.	Tons.	Years.	Tons.
1841	2,881	1851	243,014
1842	20,398	1852	129,889
1843	30,002	1853	123,166
1844	104,251	1854	235,111
1845	283,300	1855	305,061
1846	89,203	1856	200,000
1847	82,392	1857	288,362
1848	71,414	1858	353,541
1849	83,438	1859 (10 months)	73,647
1850	116,925		

The subject of the relative value of fertilising ingredients in guano, and in other manures, has been largely discussed. Professor Anderson of Glasgow, at a meeting of the Highland Society, stated the following figures to indicate, according to the authorities named, the value per ton of the principal ingredients as obtainable in guano :—

	Way.			Hodges.			Nesbit.			Anderson.		
	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
Ammonia	56	0	0	56	0	0	60	0	0	56	0	0
Insoluble phosphates	7	0	0	7	0	0	8	0	0	7	0	0
Soluble phosphates	32	18	0	25	0	0	24	0	0	28	0	0
Potash	30	16	0	20	0	0		..		20	0	0
Alkaline salts	1	0	0	1	0	0	1	0	0	1	0	0
Organic matters	1	0	0	0	10	0	1	0	0		..	

These are the prices at which these several ingredients are purchased in guano at present prices. Can they be procured elsewhere at a cheaper rate? The ammoniacal liquor of the gas works, after having been once distilled, can be obtained containing 20 per cent. of ammonia at a price which gives that substance at from 3*d.* to 3½*d.* per lb., or about 28*l.* per ton. The objection to its use is, that the ammonia exists there chiefly as carbonate, and in that state is peculiarly liable to loss by evaporation. It is clear, however, that if concentrated gas liquor were applied to the soil, the farmer could afford to lose one-third of it, and still have his ammonia cheaper than in the state of sulphate. The application should be of 2 to 3 cwts. per acre on grain crops, both alone and mixed with a certain quantity of bone ash, and the land should be made up in ridges, and the solution, diluted to a proper extent, poured into the bottom of the furrows, while the plough, immediately following the application, should be made to divide the ridge and cover the ammonia. This should be done several days before sowing, for it would not answer to put the seed near the strong ammoniacal fluid, and a few days should be allowed for it to disseminate itself through the soil. One hundredweight and a half of the ammoniacal fluid, and the same quantity of bone ash, might also be tried on turnips, and should these applications prove successful, it will be possible to make a mixture as good as Peruvian guano at a cost of not more than 8*l.* per ton.

Mr. Finnie, of Swanstone, has recently called attention to the existing wastefulness in the use of guano. His advice included the following particulars :—Government should investigate every source from which a supply of guano can be obtained; we should encourage manufacturers by making trial of other portable manures; we should turn our attention more than ever to the dung heap at home; and, lastly, instead of employing guano by itself as formerly, for turnips and barley, on the lighter and weaker description of soils, let farmers use along with it an admixture of other manures, such as bone meal, dissolved bones, or even guano of a secondary class; and for turnips and potatoes on the heavier character of soils, employ along with guano some other nitrogenous manure, such as rape dust, blood manure, &c.

Thus :—Superphosphate, along with farm-yard manure, is quite a sufficient substitute for guano for Swedes. Apply 3 cwt. per acre, along with 10 or 12 tons of dung. Nitrate of soda, 1 or 1½ cwt., is better applied to corn crops, if used in place of guano. 1½ or 2 cwt. of sulphate of ammonia per acre is a good dressing for an acre of wheat. If you can buy good soot at 6*d.* to 8*d.* a bushel, you can find no cheaper dressing than 40 bushels of that per acre. If you cannot get that, apply ½ cwt. of nitrate of soda and 1 cwt. of Peruvian guano per acre broadcast, in showery weather if possible.

On the application of guano to the soil, Mr. Nesbit gives the following instructions :—

(1.) Guano is best applied in damp or showery weather.

(2.) Guano should not generally be put on grass land in the spring later than April.

(3.) When guano is applied to arable land, it should immediately be mixed with the soil, either by harrowing or otherwise.

(4.) When wheat is sown very early in the autumn, a less than usual amount of guano must at that time be applied, and the rest in the spring. The wheat otherwise might become too luxuriant, and be injured by subsequent frosts.

(5.) Guano, and artificial manures in general, should be put on the land only in quantities sufficient for the particular crop intended to be grown, and not with the intention of assisting the succeeding one. Each crop should be separately manured.

(6.) Guano, before application, should be mixed with at least from five to six times its weight of ashes, charcoal, salt, or fine soil.

(7.) Guano should on no account be allowed to come in direct contact with the seed.

An artificial guano may be easily compounded by an admixture of the constituents of natural guano, all of which, with the exception of bone-dust, may be procured of any druggist. Professor Johnston gives the following recipe for an artificial manure which will produce an effect about equal to 1 cwt. of natural guano :—78¾ lbs. bone-dust, 25 lbs. sulphate of ammonia, 1¼ lb. of pearlash, 25 lbs. common salt, 2¼ lbs. dry sulphate of soda; total, 132¼ lbs. The following artificial substitute for guano has been successfully used, at the rate of 5 cwts. per acre :—

Bones, dissolved in spirits of salt instead of oil of vitriol		18¾ lbs.
Charcoal powder	about	18¾
Sulphate of ammonia (gas salt)	about	9½
Common salt	about	9½
Gypsum		9½
Wood ashes	about	46
Nitrate of soda (cubic petre)		28
Sulphate of soda (Glauber salts)		10
Sulphate of magnesia (Epsom salts)		10
		160 lbs.

Three or four cwts. of guano, which is the usual quantity applied one acre, have often proved equal in effect to fifteen tons of farm-yard dung. Mr. Lawes, an experienced agricultural chemist, gives the following table of the constituents of these two quantities :—

Four Cwts. of Guano contain	
Phosphate of lime	112 lbs.
Ammonia	54
Organic matter	171
Potash, soda	30
Fifteen Tons of Dung contain	
Phosphate of lime	100 lbs.
Ammonia	195
Organic matter	8505
Potash, soda, and silica	1335

Experiments have indeed been made, the results of which showed that 3 cwts. of good Peruvian guano were equal in their immediate effect to 20 tons of good farm-yard dung; but much is required to be known of the composition of a soil, and of the crops which it is to yield, before the exact value of any manure for that soil and crop can be fully settled; and this can only be ascertained by extensive experiments under every variety of local circumstances. The question may also arise, whether guano and other stimulating fertilisers do not exhaust the land while they produce great immediate results. They may, by supplying ingredients in which the soil is deficient, enable the plant so to use up others present in the land, that the soil shall be poorer after the crop has been removed than it was before the manure was applied. In this way it is that certain "artificial" fertilisers are called stimulating, and that farm-yard dung is alone a complete manure.

For various crops the guano answers best after vegetation has commenced; and it is useful in some cases to apportion the quantity intended to be used per acre into two or three portions for sowing at intervals, but the intervals most favourable are not fully determined. For small allotments or gardens it is often most convenient to use guano in a liquid state, in which case 4 lbs. of guano may be mixed with 12 gallons of water, and used after it has stood twelve hours, and the proportion per acre may be from a half to one cwt. of guano to 160 gallons of water.

GUARANINE ($C_{16}N_4H_{10}O_4$), a substance identical with theine and caffeine, and found in the *Guarana officinalis.* [Caffeine.]

GUARD is a detachment of troops appointed to watch a position to prevent surprise, or to take care of stores, baggage, &c.

GUARDIAN, one who has the care of a person and his property, who, by reason of his imbecility or want of understanding, is in law considered incapable of acting for his own interest. Guardians in the English law are appointed only to infants, though under the civil law they were also assigned to idiots, lunatics, women, and sometimes prodigals. The laws of England indeed provide for the protection of idiots and lunatics, but the rules relating to them will be more conveniently considered under those heads, and therefore we shall here confine our remarks to guardians of infants. The guardian under the civil law was either a tutor or a curator. [CURATOR.] Guardians were appointed either by the will of the father, by the disposition of the law, or by the magistrate; and accordingly, with reference to its origin, the guardianship was styled *testamentaria*, *legitima*, or *dativa*. The nature of guardianship under the civil law is fully explained in the 'System des Pandekten-Rechts' of Thibaut, i., p. 377.

The usual division of guardians, according to the English law, and therefore the most convenient order in which to explain their office, is:—1. Guardians by the common law. 2. Guardians by custom. 3. Guardians by statute.

I. Guardians by the common law were of four kinds: guardians in chivalry, in socage, by nature, and for nurture.

Guardianship in chivalry is now abolished by the statute of 12 Car. II., c. 24, which extinguished the onerous portions of the feudal system. This guardianship arose wholly out of the principles of tenure, and it could only take place where the estate vested in the infant by descent. All tenants by knights' service, being males under 21, or females under 14, at the ancestor's death, were liable to it; and it continued over males till 21, over females till 16 or marriage. It extended over the estate as well as the person of the infant, and entitled the lord to make sale of the marriage of the infant under the restriction of not making it a marriage of disparagement, and to levy forfeitures if the infant refused the marriage, or married, after tender of an alliance by the lord, against his consent. The lord was bound to maintain the infant, but subject to this obligation he was entitled to the profits of the estate for his own benefit. This guardianship, being considered more an interest in the guardian, than a trust for the ward, was saleable; and if not disposed of, passed at the lord's death to his personal representatives.

2. *Guardian in Socage.*—This also, like the former, is a consequence of tenure, and takes place only where lands of socage-tenure descend upon an infant under the age of 14. Upon attaining that age, the guardianship in socage ends, and the infant may appoint his own guardian. The title to this guardianship is in such of the infant's next of blood as cannot have the estate by descent in respect of which the guardianship arises, lest, it is said, the lamb should be delivered to the wolf to be devoured. This precaution springs perhaps from too great a mistrust of human nature, and it seems that in the early period of the Roman republic no such distinction was made. No provision upon the subject exists in the laws of the Twelve Tables—the lawgiver did not imagine that the life of the heir was in danger, though it was put in the hands of the person who would reap a benefit by his death. (Montesq., b. 19, c. 24.) And even at a subsequent period no such rule was known to the civil law; and indeed such a rule could have no place in the Roman system of succession. By the laws of Solon, no one could be a guardian who was to enjoy the estate of the ward after his death, and such it has been shown is the law of England with regard to guardians in socage. The laws of Scotland and the old laws of France prescribe a middle course: the estate is entrusted to the next in succession, because he is most interested in preserving it from waste, but he is excluded from the custody of the person of the ward. This is the principle upon which the Court of Chancery proceeds in its management of lunatics and their estates. [LUNACY.] The 'Code Civil' of France, b. 1, tit. x., ch. 1, 2, 3, has many provisions relating to guardianships, too numerous to mention here. The guardian in socage is entitled not only to the custody of the person and socage estates of the infant, but also to his hereditaments not lying in tenure, and even his copyhold estates, where no custom to the contrary exists in the manor of which they are held, and also his personal property. The guardianship in socage is regarded as a trust wholly for the infant's benefit, and is not saleable, or transmissible, but in the event of the death of the guardian the wardship devolves on the person next in degree of kindred to the infant, not being inheritable to him, and the guardian is accountable to the infant for the profits of his estate.

Guardianship in socage is, however, superseded both as to the person and estate of the infant, if the father appoints a guardian according to the statute, as will shortly be mentioned.

3. *Guardian by Nature.*—This species of guardianship has no connection with the rules of tenure. It extends only to the custody of the infant's person, and lasts till he attains 21. Any ancestor of the infant may be such a guardian, the first right being in the father, the next in the mother, and if they be dead the ancestor to whom the infant is heir has a right to the custody of his person. Until 14, it seems the guardian in socage is entitled to the custody of the person, and after that age the guardian by nature.

4. *Guardians for nurture* are the father and mother of the infant; in default of father or mother, the Ordinary, it is said, may appoint some person to take care of the infant's personal estate and to provide for his maintenance and education, though this has been doubted. This species of guardianship extends only to the age of 14, in males and females. Both these last descriptions of guardianship are also superseded by the appointment of a guardian by statute.

Where an infant is without a guardian the Court of Chancery has power to appoint one, and this jurisdiction seems to have vested in the king, in his Court of Chancery, as *Parens Patriæ*, upon the abolition of the Court of Wards. [CHANCELLOR.] And where a proper case exists for the jurisdiction of this court, it will, treating all guardians as trustees for their wards, interfere not only with the property of the infant, but also with the custody of his person, and will, in case of any misbehaviour, remove a guardian, however he may have been appointed or constituted, and will appoint a proper guardian to the infant in his room. Of this jurisdiction an instance is afforded by the case of the Duke of Beaufort *v.* Wellesley—where, the father being alive, Lord Eldon upon moral grounds deprived him of the custody of his children—and this power of the Court of Chancery is now firmly established. And though the infant may have elected and appointed a guardian, this will not exclude the jurisdiction of the Court of Chancery, but upon the case being brought before the court it will order an inquiry as to the fitness of the guardian appointed. All courts also have power to appoint a guardian *ad litem*, that is, to defend a prosecution or suit instituted by or against an infant. ('Co. Litt.,' 88 b, Hargr. note.)

II. *Guardians by Custom.*—By the custom of the city of London the guardianship of orphans under age and unmarried belongs to the city; and in many manors particular customs exist relating to the guardianship of infants; but in the absence of any such, the like rules prevail as before mentioned of guardians in socage.

III. *Guardians by Statute.*—At common law no person could appoint a guardian, because the law appointed one in every case. The statute 4 and 5 Phil. and Mary, c. 8, seems to have given some powers to the fathers of infants to appoint guardians; but guardians by statute are now appointed by virtue of 12 Ch. II., c. 24. Under this statute fathers, whether under age or of full age, may, by deed or will attested by two witnesses, appoint any person or persons (except Popish recusants) guardians of their unmarried children until they attain 21, or for any less period. A guardian appointed under this statute supersedes all other guardians, except those by the custom of London, or any city or corporate town in favour of which an exception is made, and is entitled to the custody of the infant's person, and his estate, real and personal. If two or more persons are appointed guardians under the provisions of this statute, the guardianship remains to the survivor. By the wording of the statute a *father* alone is empowered to appoint a guardian, and consequently, though the omission was probably unintentional, it has been decided that neither a mother, nor grandfather, nor any other relation, can make such an appointment. Neither can a father appoint a guardian to his natural child: but in all these cases the Court of Chancery will appoint the persons named to be guardians if they appear to be fit persons to exercise the trust reposed in them.

Guardians are rarely now appointed by infants themselves, the jurisdiction of the Court of Chancery providing far safer and more effectual means for the management and control of their property; and since in many cases the Court will interfere by petition without the institution of a suit, a cheap and speedy mode of procuring its interference is afforded. The guardian is considered as a trustee for his ward, and is accountable for the due management of the infant's property, and is answerable not only for fraud, but for negligence or omission.

Guardian of the Spiritualities is the person to whom the spiritual jurisdiction of any diocese is committed during the vacancy of the see.

Guardian of the Temporalities is he to whom the temporal jurisdiction and the profits of the see are committed during the like period.

The words guardian and warden are of the same signification: indeed, they were formerly used indifferently. Thus the warden of the Cinque Ports was styled guardian, or in the old French, gardeyn, and churchwardens, gardeyns del Eglise. The Welsh word qward is the same as the English guard.

GUELPHS and GHIBELLINES, the names of two great political parties which divided Italy and Germany during the middle ages, became first known as the watchwords of their respective adherents at the battle of Winsberg, in Suabia, between two rivals for the Imperial throne, Conrad, duke of Franconia, and Henry the Lion, duke of Saxony, of the house of Guelph, Welf, or Wölf. Welf, who was young Henry's uncle, fought on behalf of his nephew, and his name was the war cry of his followers; whilst those of Conrad took for their rallying word the name of Waiblingen, a town of Wurtemberg, and the patrimonial seat of the Hohenstaufen family, to which Conrad belonged. [CONRAD III. in BIOG. DIV.] In course of time the name of Guelphs was given to all who were disaffected to the Emperor, and that of Ghibellines (which the Italians had formed from the German Waiblingen) to the supporters of the Imperial authority; and as the popes, reviving their old rivalry with the empire, encouraged and supported the disaffected Guelphs, they became at last the leaders of that party, and the Italian cities were divided between the adherents of the popes and those of the emperors. The names of Guelphs and Ghibellines were not however generally adopted in Italy till the reign of Frederic II., when Italy was divided, as it were, into two camps; some cities, such as Florence, Milan, Bologna, ranging themselves on the Guelph side, while Pisa, Arezzo, Verona, and others, remained

Ghibelline. The Ghibellines adopted as a symbol a white rose or a red lily; the Guelphs chose the eagle, already the arms of the Guelph family. But in the long struggle that ensued many alternate changes took place in each city, where sometimes the Guelphs, and sometimes the Ghibellines, gained the upper hand. [Florence; Genoa, History of, in Geog. Div.] Most of the powerful nobles in Northern Italy, the Visconti, Doria, Della Scala, Pelavicino, were Ghibellines; the Anjou dynasty, which the popes had called to the throne of Naples, were the main support of the Guelphs. As the emperors, engrossed by their German affairs, neglected and dropped their hold upon Italy, the names of Guelph and Ghibelline lost their original meaning, and the struggle became one of personal or municipal ambition among the Italians themselves, the Ghibellines being for the most part animated by a spirit of aristocracy, the Guelphs professing to be favourers of a popular form of government. [Dante, in Biog. Div.] But even this distinction was often belied by facts, and the leaders of the Guelphs in some towns tyrannised over their countrymen; whilst in some instances, as at Genoa, the Ghibellines formed really the popular party. In the 15th century the names of Guelphs and Ghibellines had become a mere traditional shadow, and at last the popes themselves united with the emperor in extinguishing the independence of the Italian republics, without distinction of parties. (Sismondi, 'History of the Italian Republics;' Raumer, 'Geschichte der Hohenstaufen.)

The House of Guelph, originating in Italy, settled in Germany in the 11th century, and very shortly acquired large territorial possessions. From this family has proceeded both the lines of Brunswick-Oels and Luneburg; it gave emperors to Germany, dukes to Saxony, Carinthia, and Bavaria; one branch became also Dukes of Este in Italy, and the House of Hanover claims descent from both branches. [Brunswick, History of, in Geog. Div.; Este, in Biog. Div.]

GUERITE is the term applied in fortification to the projecting masonry sentry boxes to be seen in many old fortresses, at the salient angles of works on the top of the revetment. They are provided with loop-holes, so as to enable a few men in them thoroughly to command the foot of the escarp along the whole extent of the face. They have, however, the disadvantage of enabling an enemy the more easily to take up the prolongation of works to place his enfilade batteries, by giving well marked points at the extremities of the faces: they have, therefore, not been much used of late years.

GUILDS. [Municipal Corporations.]

GUILLOTINE, an instrument for the infliction of capital punishment, proposed to the National Assembly of France by Joseph Ignace Guillotin, a physician, a native of Xaintes, and a member of the Assembly; and which from him took its name. It was adopted by a decree of the 20th of March, 1792, and used for the first time on April 25th.

This instrument, under other names, had existed as a means of public execution long before, in Germany, Bohemia, Italy, Scotland, England, and even in Persia and India.

Crusius in his 'Annales Suevici,' fol. 1595-6, tom. ii., p. 296, says, 'Antiquis autem temporibus, in Germania etiam, decollatio non gladio fiebat, sed querno ligno, habente scindens acutissimè ferrum. Addit Widemannus, se vidisse tale instrumentum Hale in vetere Nosodocheo (Siechaus) priusquam id destrueretur: et hodiernum ibi ædificaretur. Efferebatur inde illa machina, si quis plectendus esset: supplicioque peracto, eodem referebatur."—" Postea usus gladii successit."

In German this instrument was called *der Planke der Deil* (the plank of wood), and in older language *Falbeil* (the falling hatchet). In Bohemia it was called *Hagec*, something akin to the plank. In Italy it was known by the name of *Mannaia*, and an engraving of it may be seen in 'Achillis Bocchii Bonon. Symbolicarum Questionum,' lib. v., 8vo., Bonon, 1555, p. 36. There is a very beautiful engraving of the German instrument in a representation of the beheading of the son of Titus Manlius, by Henry Aldegrevers, dated 1553. Evelyn, in his 'Memoirs,' vol. i., p. 170, states that he saw a similar instrument at Naples.

Pennecuik, in his 'Description of Tweeddale,' pp. 16, 17, speaking of the Regent Morton of Scotland, says: "This mighty earl, for the pleasure of the place and the salubrity of the air, designed here a noble recess and retirement from worldly business, but was prevented by his unfortunate and inexorable death, three years after, anno 1581, being accused, condemned, and executed by the *Maiden* at the Cross of Edinburgh, as art and part of the murder of King Henry, earl of Darnley, father to King James VI., which fatal instrument, at least the pattern thereof, the cruel Regent had brought from abroad to behead the Laird of Pennecuik of that ilk, who notwithstanding died in his bed, and the unfortunate earl was the first himself that handselled that merciless *Maiden*, who proved so soon after his own executioner."

In England, what has been since called the Guillotine was used only at Halifax in Yorkshire, and confined even there to the punishment of felonies committed within the forest of Hardwick. Its use at Halifax is traced as far back as the time of Edward III. It was in 1650 that the last malefactors there suffered by it. (Watson's 'Hist. of Halifax,' p. 214-239.)

Joseph Ignace Guillotin, who revived the use of this instrument, in France, is supposed, by many, to have perished at a later period of the Revolution, like the Regent Morton, by his own invention. But this is not correct. He died a natural death, 26th May, 1814, at the age of 76. ('Biogr. Universelle.')

GUINEA. [Money.]

GUITAR, a musical instrument which, in various shapes, may be traced to the remotest periods of antiquity. The word is derived from the Greek κιθάρα, and comes immediately to us through the French *Guitare*, though it is nearly the same in the Italian, Spanish, and German languages. The terms *Cittern* and *Gittern*, used by the old English poets, are but corruptions of the primitive word.

The English and French guitar of the last century was wide and thin in body, short in the neck, and strung with wire. The modern guitar, which is of the Spanish kind, and differing little from the lute, consists of a body from seventeen to eighteen inches in length, four in depth, and of a neck of about sixteen inches, the latter carrying a finger-board divided by seventeen frets. It has six strings, three being of silk covered with silvered wire, and three of catgut.

The compass of this elegant instrument is from E below the base staff, to A above the treble staff, including all the intermediate tones and semitones. The best and cheapest guitars are made in Germany, and may be purchased in London at a moderate price.

GUM is a proximate principle of vegetables, of more universal occurrence than any other secretion by plants. It is in reality the material generally prepared by them for their own growth and nourishment, and is at first always in a state of solution, in which condition it mostly remains so long as it is contained in the internal tissues of plants; but when it escapes to the exterior of the bark it frequently becomes thickened, and even solid and pulverisable. It is probable that it never escapes to the surface unless some wound of the bark has been made, either by disease, the punctures of insects, the agency of fungi, by the knife, or by the more rapid growth of the inner wood, producing by its distension a rupture of the bark. The escape of the gum termed *cerasin* from plum and cherry trees may always be regarded as an indication of unhealthiness; the immediate cause of escape is the presence of a small corkscrew-like fungus termed *Næmaspora crocea*.

Gum is known in commerce only in the solid state; the term is often erroneously applied to substances which are a mixture of gum with resins, and which are properly *gum-resins*, such as ammoniacum, asafœtida, and the like, and even to substances which contain no portion of gum, such as euphorbium.

Arranging the gums according to the facility with which they are acted upon by water, we have at one end of the list gum-acacia, or gum-arabic as it is most usually called, and at the other end gum-tragacanth. Gum-arabic forms a perfect solution with even cold water, and to this variety of gum the term *arabin* is given; gum-tragacanth on the other hand, though swelling up immensely when digested in water, and at first sight appearing to form a solution, does not really dissolve, but forms a thick mucilage, and to this modification of gum the term *bassorin* is applied. The derivation of the name arabin is obvious, that of bassorin is obtained from *bassora gum*, a variety of tragacanth that comes from Bassora, and which contains scarcely a trace of arabin. Other members of the series of true gums are mixtures in variable proportions of these two gum modifications.

Arabin ($C_{12}H_{11}O_{11}$) is colourless, tasteless, and inodorous. Specific gravity, from 1·3 to 1·5. It is uncrystallisable. Its solution slightly reddens litmus-paper, and rotates to the left a polarised ray. Dilute sulphuric acid converts it first into dextrin and then into grape-sugar; strong sulphuric acid carbonises it: nitric acid converts it into mucic and oxalic acids. It forms soluble compounds with the alkalies and alkaline earths. It is precipitated from solution by persalts of iron, proto-salts of mercury, and subsalts of lead. The reaction with persalt of iron is characteristic of arabin: if the solutions are strong, a brown gelatinous precipitate is formed, soluble with difficulty in boiling water; if the solutions are weak, a yellowish precipitate is produced only after the lapse of some time; thus one part of gum-arabic in 100 parts of water gives a precipitate with persulphate of iron after the mixture has stood for twenty-four hours.

Bassorin is soluble in dilute acids or alkalies, and by very long boiling even in water, but in each case it is probably converted into arabin. Like arabin it is insoluble in alcohol or ether, and is oxidised by nitric acid to mucic and oxalic acids. The presence of bassorin gives the peculiar mucilaginous or viscous consistence to the decoctions of linseed, quince-seed, marsh-mallow root, &c.

Most of the commercial gums are obtained by incisions made in the bark of several species of acacia growing in Arabia, India, Upper Egypt, Senegal, &c. The specimens differ considerably in colour, even when obtained from the same species. Genuine gum-arabic occurs in pieces from the size of a pea to that of a walnut, or larger, which are irregular in shape, or roundish or angular; either white, yellowish, or dark wine yellow; scarcely any odour; taste mawkish, glutinous. Sp. gr. 1·316 to 1·482. It breaks easily into small irregular pieces; fracture uneven, vitreous; dissolves almost completely in water; 100 parts of water at 212° of Fahr. take up 19 parts of gum. The solution is almost transparent when made with cold water. Gum, when in powder, is often adulterated with starch, the presence of which is detected by tincture of iodine; or when cold water is used for the solution of the gum, the starch will remain undissolved. The mucilage made with cold water is not only purer, but keeps better, and for all purposes for which it can be used is preferable to that made with warm water, which is the common method.

Gum is not very easily digested when taken alone, and will often pass through the stomach nearly unchanged, if not associated with some bitter or astringent principle. Hence the advantage of some bitter extractive or astringent principle, either in the grasses themselves or in other plants, such as *tormentil* or lesser *centaury*, interspersed in the pasture lands of cattle. (See Davy, 'Agricultural Chemistry;' or Sinclair, 'Hortus Gramineus Woburnensis.') This property, however, renders it demulcent in affections both of the throat and also of the intestines, by sheathing the membrane from air or the irritation of acrid secretions. Hence allowing a portion to dissolve slowly is often useful in common colds. Mucilage is also used to suspend many insoluble matters in water. Its agglutinating properties render it valuable in many of the arts.

GUM-RESINS are secretions of plants which are produced in the greatest quantity, and most perfectly elaborated, in warm countries. They are obtained chiefly from trees and shrubs of particular tribes of plants, rarely from herbaceous plants, except the large herbaceous *Umbelliferæ,* which yield the fœtid gum-resins. They either exude spontaneously, or are procured by incisions of the stem and branches. When they first escape to the surface they are fluid, and of a light colour, but gradually harden, and become of a deeper hue, either by the evaporation of some of their volatile oil, or by the absorption of oxygen from the air, and the conversion of the oil into a resin. Some remain in a semi-liquid, viscid state, such as sagapenum and galbanum, which are only pulverisable in winter. Most gum-resins possess a strong odour, which in many instances is disagreeable, such as that of asafœtida, with a warm acrid taste, and by application to the skin for any considerable time they cause redness and inflammation. Owing to their composition being a mixture of gum and resin, they are not completely soluble either in water or absolute alcohol, but are perfectly dissolved in proof-spirit, which is much employed to prepare tinctures of this class of substances. The gum being soluble in water is capable for a time of holding the resinous portion suspended in water, thereby forming an emulsion,—a state which permits of their administration, if used soon after being prepared; for by rest they separate. Many of them are soluble to a certain extent in acetic acid, especially when assisted by heat. The strong mineral acids char them and produce chemical changes. Many gum-resins are popularly termed balsams, a designation to which they have no title, as they do not contain benzoic acid.

Gum-resins are with difficulty soluble in the animal juices, yet, as they must be assimilated before they produce their characteristic effects, they require to be used for some time before the secretions of the body acquire their peculiar odour. They influence the secretory and excretory processes, which they rouse to continued action. They also act upon the skin as sudorifics, and more permanently than the volatile oils. They manifest their beneficial effects chiefly when the skin is cool, pale, and in a state of atony; and they can even check profuse perspiration, when this is caused by the lax state of the cutaneous tissues. They are likewise possessed of considerable antispasmodic powers, and hence are much used in nervous complaints. They greatly promote digestion when the stomach is feeble, owing to a defective supply of nervous energy. Their utility in the treatment of hysterical and other paroxysms is very much increased by administering them in a state which admits of ready solution in the gastric fluids; hence the acetous preparations of them are much more potent than any other form. They may be administered either by the mouth, or, in case of spasm closing the teeth, or the patient being refractory, in the form of clyster, the dose being doubled in the latter instance.

Gum-resins are likewise applied externally, owing to their rubefacient powers, in the form of liniments or plasters, in spasmodic and rheumatic affections, and also to assist in dispersing indolent tumours.

Gum-resins should be kept in cool well-closed places, to prevent the evaporation of their volatile principles.

GUMS AND GUM-TRADE. Professor Solly, in a paper on the subject of Gums, read before the Society of Arts, recommended to drug-brokers the adoption of a more exact classification than at present prevails, between gums, resins, and gum-resins. Dealers and brokers know very well what they mean; but they are not so precise as chemists in the nomenclature adopted. The distinctions recommended are as follow. *Gums* to comprise those natural vegetable exudations which soften or dissolve in water, and yield a more or less perfect mucilage, but which are wholly insoluble in spirit; *resins* to comprise those fusible and combustible vegetable substances which are quite insoluble in water, but which soften and dissolve in spirit, ether, or essential oil; and *gum-resins* to comprise those natural products which are intermediate in properties, and partake of the nature both of gums and resins, being partially and imperfectly soluble both in water and in spirit.

Different kinds of gum, limited and defined as above, are extensively used in the arts, especially in finishing and giving lustre to crape and silk goods, and in numerous processes of calico printing. One kind alone, *Gum Senegal,* has been imported by a single Liverpool firm to the value of 100,000*l.* in three years; and the export of gum from Alexandria has often reached 140,000*l.* per annum. The Cape colonists established a trade with the Kaffirs, a few years ago, for gum which was obtained from the *mimosa* tree, and which was sent to England for the use of calico printers, calenderers, envelope makers, &c.; the trade afterwards fell off, through the invention or discovery of *British gum*, presently to be described. The east and west shores of the Red Sea are the chief sources for *gum arabic* (which scarcely differs from gum senegal); from two to three hundred tons pass annually through the Custom House of Aden alone. Large quantities are collected by persons in the employ of the Egyptian government, and brought in caravans to Cairo to be warehoused; in recent years, the quantity has averaged about 20,000 packages of 78 lbs. each. The produce of Morocco is packed in very large leather sacks, and conveyed on the backs of camels and bullocks to the ports, where it is sold to English and French merchants; during the whole time, from the collecting to the sale, including the land journey, the natives live almost wholly on the gum, a few ounces being sufficient to support a man for twenty-four hours. A gum exuding from the *Macarung* or *Indica* in Travancore, is occasionally used for taking impressions of leaves, coins, medallions, &c.; when this gum is pure and carefully prepared, the transparent casts are as sharp as those of sulphur, without its brittleness.

The gums proper are most largely used in the stiffening of textile materials; the resins proper are, for the most part, used in the making of varnishes and lacquers, in dyeing, in paper-making, and in making sealing-wax. The gum-resins are mostly used in medicine. Many of these substances are of sufficient importance to occupy separate articles in this division of the Cyclopædia; while the general character of the uses of others can be inferred from the observations just made.

For some delicate processes in the arts, gum arabic and gum senegal require to be purified. The following is one mode, patented a few years ago, for effecting this:—A solution of purified sulphurous acid gas being prepared, the gum is dissolved in it, with exclusion of atmospheric air. The earthy and ligneous impurities fall to the bottom; the colouring matters combine with the gas; and the carbonic acid is driven off by the application of heat. Carbonate of baryta, or some other solidifiable base, is added; this combines with the sulphurous acid and forms a neutral salt. The solution is then filtered through a pure gelatinous hydrate of alumina; and is finally dried by heat, either in the open air or in vacuum pans.

Mention was made above of *British gum,* as a substance which has lessened the use of foreign gums in this country. According to an account given by Mr. Simmonds, a fire on one occasion broke out in a potato-starch manufactory in Dublin. The burning building was deluged with water by the fire-engines, and the starch was washed about in every direction. One of the workmen fell down, and had his clothes soaked with the calcined starch and water. He thought no more of it till the next morning; when, upon dressing himself, he found the sleeves of his coat, the legs of his trousers, and the linings of his pockets, glued up so that he could with difficulty open them. On revisiting the scene of the fire, he discovered that the glutinous properties were possessed by the potato starch; and by a few simple experiments, a discovery was completed which has resulted in large profits. Under the names of *British gum, dextrine,* and *gum-substitute,* a new substance appeared in commerce, and became largely employed in the arts. It is nearly equal to gum arabic in adhesiveness, less affected by climate, and less than one-fourth of the price. It forms the main ingredient in the adhesive composition for envelopes and postage-stamps. For the chemical qualities of this substance, see DEXTRINE.

It is not easy to state the quantity and value of gums, resins, and gum-resins imported into this country, and mostly used here in manufactures and in medicine. They are scattered about under so many headings in the official lists, and are entered under such different forms, that they can scarcely be recorded collectively. The Liverpool importation amounted, a few years ago, to 2200 tons annually, including the heavy items of turpentine, resin, caoutchouc, and gutta-percha; but the importation of the last two substances has since prodigiously increased. [CAOUTCHOUC; GUTTA-PERCHA.] Four of the most costly substances in the above list, those which present the most value in the smallest space, were imported into the United Kingdom in the following quantities and values in 1856:—

	Cwts.	£.
Gum copal	6,300	16,700
Gum arabic	70,900	120,800
Lac dye	11,000	37,300
Shell lac	14,800	34,700

Many varieties of gum are included in the official entry, Gum arabic.

GUN is a term now generally applied to the larger description of fire-arm, but as a description of the principal varieties of fire-arms, both large and small, with notices respecting the dates of their invention, is given under ARMS and ARTILLERY, and under CANNON is an account of the manufacture of great guns, we shall here supply a notice of the manufacture of the smaller kinds of fire-arms, to which the names of musket or musquet, fowling-piece, &c. are applied.

The rise of the gun manufacture in Birmingham, which is its principal seat in this country, appears to date from about the commencement of the 18th century. Hutton, in his 'History of Birmingham' (pp. 78, 79, of the edition of 1781), relates that, according to tradition, King William III. was once lamenting that guns were not manufactured in his own dominions, but that he was obliged to procure them, at great expense, and with greater difficulty, from Holland; when Sir Richard Newdegate, one of the members for the county, who happened to hear him, observed that genius resided in Warwickshire, and that he thought his constituents would answer his majesty's wishes. The king being pleased with the remark, the member posted to Birmingham, where the pattern was executed in such a manner as to give entire satisfaction. Large orders were immediately given, and these were so frequently repeated that, to quote Hutton's quaint expression, the manufacturers never lost their road. From notices in Macpherson's 'Annals of Commerce' it appears that about 1787 the manufacture was prosecuted with great activity for the supply of foreign markets, the manufacture of Birmingham guns for the African market being estimated to give employment to between four and five thousand persons. By one of the strange perversities of taste, of which many examples may be found in the history of manufactures, guns marked "London" were long preferred to those marked "Birmingham," notwithstanding the well-known fact that Birmingham was the chief seat of the manufacture. The Birmingham manufacturers were thus induced to stamp their goods as if made in London; and when, in 1813, a bill was brought into the House of Commons to compel every manufacturer of fire-arms to mark them with his real name and address, they took the alarm, petitioned against the bill, and instantly subscribed a large sum to defray the expense of opposing it, urging that they made the component parts of the London guns, which were, in fact, only put together and marked in the metropolis. The bill was defeated, and shortly afterwards the Birmingham gun-makers were allowed to erect a proof-house of their own, and to mark their guns, after being subjected to the proof required by the Board of Ordnance, with a distinguishing stamp. Holland, in the work referred to at the close of this article, gives some curious information respecting the extent of the gun-manufacture of Birmingham, both during the protracted war in which England was involved at the commencement of the present century, and more recently, when English artisans have been employed to meet the demands of foreign states. From his statements, founded upon authorised returns, it appears that more than two-thirds of the fire-arms made for the Board of Ordnance were supplied from Birmingham, and that the stands of arms fabricated there for the British government in the years 1812 and 1813 amounted respectively to 288,741 and 320,643. During the period of greatest activity it is said that the Birmingham manufacturers produced a musket per minute, which is not an extravagant assertion, seeing that, supposing the work to be carried on for sixteen hours every day in the year, Sundays excepted, the number produced at that rate would be 300,240, or rather under the number supplied to the government alone in 1813. The contract price at that time was 36*s*. a gun; but with the peace came a great falling off in the demand, which led many gunsmiths to abandon the trade, and caused a great reduction of price. In 1830 the Birmingham gun-makers contracted with the French government for the supply of 140,000 stands of arms at the price of about 28 francs, or rather under 23*s*. per gun, and even that price, Holland states, was considered liberal. It has been repeatedly stated by M'Culloch and others, that between the years 1804 and 1818 Birmingham supplied to government and the private trade nearly 5,000,000 fire-arms; and Barlow, quoting from authentic documents, shows that between 1803 and 1816, the number of fire-arms received and issued by the British government amounted to 3,227,716 muskets, 118,103 carbines, 27,895 rifles, and 203,266 pistols. In 1813 our allies alone were furnished with 500,000 muskets.

The most essential part of a gun is the *barrel*, or cylindrical iron tube, closed at one end, in which the explosion of the gunpowder is produced, and through which the ball or shot is projected. The interior of the barrel, which is technically called the bore, is in the musket a perfect and smooth cylinder, but the exterior is made slightly conical; that is, roughly proportionate at each point to the disruptive force of the gunpowder, thicker at the *breech*, or closed end, where this is greatest, and tapering to the *muzzle* where it is least. The very severe trials to which the barrel of a gun is exposed in use, and the fearful results which attend its bursting, render it in the highest degree important to use none but iron of good quality in the manufacture, and to work it in such a way as to render the chance of failure as remote as possible.

Military muskets generally, and the cheaper descriptions of other guns, have their barrels formed of tenacious soft iron, which is wrought or rolled into the form of flat bars, called *skelps*, each of which is sufficient to form a single barrel. The length of a skelp is usually about three feet, and the breadth about four inches at one end, where also it has increased thickness or substance to form the breech of the barrel, but gradually tapering to about two inches and a half at the other end, which is to form the muzzle. Until about the year 1811, skelps were usually manufactured by means of the forge-hammer; and as considerable skill was required to ensure the regular gradation from the thicker to the thinner end, the workmen employed in forging them were able to command good wages. In the above year, however, in consequence of a strike among the skelp-forgers for what was considered an exorbitant advance of wages, a method of fashioning them by rollers was introduced, it occurring to the inventor, according to Babbage's account, "that if the circumference of the rollers between which the bar-iron was rolled, were to be made equal to the length of a skelp, or of a musket barrel, and if also the groove in which the iron was compressed, instead of being of the same width and depth throughout (as in the ordinary manufacture of bar-iron by rolling), were cut gradually deeper and wider from a point on the rollers, until it returned to the same point, then the bar-iron passing between such rollers, instead of being uniform in width and thickness, would have the form of a skelp." The experiment succeeded, not only in effecting a great saving of labour, and rendering the manufacturers independent of the refractory workmen, but also in producing skelps of superior quality. "The pure metallic particles," according to Holland's account of this invention, for which a patent was obtained by a Staffordshire ironmaster named Bradley, "being compressed by the rollers both edgeways and flatways at the same time, cohere more closely together; nor are the skelps so liable to veins or flaws as those which are edged up in a less hot state under a forge-hammer." The barrels made of them are said also to turn clearer and sounder than those forged by hand.

In the old method of welding the skelps into barrels, the thicker end was first heated to redness, and then hammered upon a groove or hollow cavity in the anvil until the edges were turned up. A mandril being then inserted in the concavity between them, the edges were turned over and welded together by the hammer. By the repetition of the like process upon a length of two or three inches at a time, the skelp was gradually converted into a tube or barrel, each of the lengths thus separately welded being exposed to two or three welding operations, with alternating high and low heats, the latter being intended to correct defects occasioned by the former. Several attempts were made to substitute the action of machinery for this tedious and laborious process, in one of which, patented in 1811 by Messrs. James and Jones, and described by Holland, the power was applied by a series of automatic hammers. Little, however, was done in bringing any such process into operation until a combination was formed among the welders, similar to that above referred to among the skelp-forgers, and which, if successful, would have caused the completion of a large contract which was then being executed to be attended with a very heavy loss. A method which had been patented some years before by one of the contractors, but which had not then been brought into satisfactory operation, was resorted to under this difficulty, and the result was, that barrel-welding by rolling machinery soon, in a great measure, superseded the old process; and the manufacture of iron tubes of lighter character, suitable for gas or water pipes, by a similar process, was subsequently commenced. Babbage, whose account of the introduction of this process we have quoted, observes that the combining workmen were thus permanently reduced to a lower rate of wages, and that as the new method of welding was far less injurious to the texture of the iron than the old, in consequence of the iron being exposed only once, instead of three or four times, to the welding heat, the public derived advantage from the superiority as well as from the economy of the process. Babbage does not mention the name of the person to whom the introduction of this improvement is due; but Greener, in his account of the same circumstances, attributes it to the late Mr. Clive, who was an extensive manufacturer of iron for gun-barrels, and states that the jealous opposition of the trade to his innovation led the Birmingham gun-makers to combine not to use his iron.

The most recent and authentic account we have seen of the modern improved method of barrel-welding is that communicated by Mr. Lovell, director of the royal arms manufactory at Enfield Chase, to Dr. Ure's 'Dictionary of Arts, Manufactures, and Mines,' under the title 'Fire-Arms,' where this method is said to have entirely superseded that of skelp-welding by hand. From this article it appears that, instead of being formed of skelps forged nearly to the intended length of the barrel, barrels are now made from flat bars of thoroughly refined iron, cut by shears into slabs ten or twelve inches long, and weighing from ten to ten and a half pounds, or less, according to the kind of barrel to be made. "These slabs, after being cut from the bars, are heated, and, to adopt Mr. Lovell's language, 'bent in their whole length, by means of conveniently grooved bending rolls, until they assume the form of rough tubes,' their opposite edges being brought to meet without overlapping. These tubes are then laid upon the hearth of a reverberating furnace, and brought to a full welding heat; and as soon as the edges come to a semi-fluid state, they are taken out and passed between grooved rollers, the grooves of which are rather smaller than the exterior of the tube. By this means the tube is perfectly welded from end to end, and if the heat be properly managed, and the juncture kept clear of dirt and cinders, the iron will become perfectly homogeneous in every part, without any appearance of the seam where the edges come together. The tubes are repeatedly heated, and passed through gradually decreasing grooves in the rollers; and to preserve their tubular form and ensure regularity in the *bore*, or internal dimension, during the welding process, they are taken out of the furnace and applied to the rollers, by means of a mandril consisting of a long iron rod considerably smaller than the bore, but having at the end a short steel treblett made exactly the size that the barrel is intended to be. By a simple contrivance it is arranged that, while the tube is passing between the rollers, the treblett shall always be immediately between them, so as to keep the bore open. The adhesion of the hot metal to the surface of the rolls or rollers is sufficient to draw the tube off the mandril. By a succession of rollings the barrel is elongated to the required length, and brought down to the required degree of tenuity; and if there be any surplus metal, it is cut off from the muzzle end. Gun-barrels formed in this way are found to stand proof better than those wrought by hand, because the heat is more equalised, and, in consequence of the great elongation between the rollers, any imperfections in the original mass of iron are dispersed over a greater surface."

All the processes hitherto described relate to the manufacture of what are termed *plain* barrels; but some of the most curious operations in the gun-maker's art relate to the manufacture of the superior kind of barrel called *twisted*, of which there are many varieties. In all of these the material of which the barrel is composed is rolled or forged into narrow bars, about equal in thickness to the intended substance or thickness of the barrel, and varying in width from about three-eighths of an inch to an inch or more. One of these narrow rods or ribands of metal, being moderately heated to increase its pliancy, is wrapped spirally round a cylindrical mandril about the size of the bore of the intended barrel, in such a way as to form a tube, which may be slipped off the mandril at pleasure. As the rods are not usually made of sufficient length for one to form a barrel, several are usually joined end to end, those which form the breech being thicker than those at the muzzle end. In this state the barrel is a coil of metal somewhat resembling, on a large scale, the kind of spiral spring employed by bell-hangers as a check-spring. It is then heated to welding heat, and forged into a solid or continuous tube, partly by hammering upon a mandril, and partly by what is termed *jumping*, or striking the end of the barrel upon the floor, by which the edges of the helical or spiral rod are brought into very close contact, and eventually incorporated together. Many successive heats are, of course, necessary in this operation, and the welding proceeds only two or three inches at a time.

The manufacture of the numerous varieties of twisted barrel is very minutely described in Greener's works, entitled 'The Gun; or a Treatise on the various descriptions of small fire-arms,' and 'The Science of Gunnery, as applied to the use and construction of fire-arms,' especially in the first mentioned, which contains many curious details upon the various kinds of iron employed. From these it appears that considerable difficulty has arisen from the circumstance that, as the progress of science has enabled manufacturers to produce articles of common use of very inferior qualities of iron and steel, the common *scrap* iron and steel, which consists of fragments of such articles when broken or worn out, and which is much sought after by the makers of gun-barrel iron, is very inferior to what was procurable a few years since. Even horse-nails, that is to say, the nails employed for fixing horse-shoes, and which when worn out are collected with avidity as furnishing one of the best descriptions of scrap-iron, under the name of *horse-nail stubs*, are now difficult to be procured of the quality required for making gun-barrels, since many of those used in this country are now made of malleable cast-iron, and a few such mixed with others would spoil the iron for the purposes of the gunsmith. *Wire-twist* is the technical name given to an excellent kind of twisted barrel, which by some ignorant dealers is supposed to be really fabricated of wire. Such barrels are formed of very narrow rods of compound metal, composed of alternate bars of iron and steel forged into one body, and then rolled out to the requisite tenuity, when the edges of the rods, which are brought to the surface of the barrel, will, on the application of a corrosive liquor, which acts differently upon the two metals, present a fibrous or wiry appearance. In forming a barrel of such rods care is taken that the adjoining edges of the spiral be alternately composed of iron and steel, so that the pattern may have a uniform appearance, although the difficulty of welding is thereby increased. *Damascus* barrels, or rather such as are manufactured in this country under that name, are composed of similar metal, but the rods are twisted upon their own axes until their component fibres or laminæ have from twelve to fourteen turns in an inch, and the rods are thereby doubled in thickness and proportionately reduced in length. Two such rods are welded together side by side, their respective twists being reversed. Barrels made of rods of Damascus iron have a very pretty appearance; but, as Greener observes, the metal is considerably weakened by the excessive twisting of its fibres, on the same principle, though not to the same degree, as a rope is impaired by over-twisting. Of this point Greener gives illustrations in the results of numerous experiments made by him on the cohesive strength of various kinds of iron. *Stub* barrels are formed of horse-nail stubs, cleaned to brightness by friction in a machine, and mixed with fragments of steel, usually of old coach-springs cut up into little bits resembling the stubs. These stubs and scraps are wedged compactly into a hoop or ring, which holds them together while they are exposed to welding heat in a furnace, and welded into a compact mass called a *bloom*, which is drawn out by rollers into the narrow strips required for making twisted barrels. Greener states that the usual proportions of this compound metal are fifteen pounds of steel to twenty-five pounds of iron-stubs; but he thinks the proportion of steel might be increased with advantage. Attempts to make barrels of steel alone have frequently failed owing to its hardness. "It is not," he observes in 'The Gun,' "sufficiently tenacious of itself, from its fineness of grain, to resist the sudden explosion of gunpowder." He states that when steel barrels have been found to stand proof, their shooting powers have been found very great, a circumstance which affords encouragement to efforts for introducing them. Some makers have tried to make iron barrels with an inner tube or lining of steel; but this appears objectionable, because the two metals thus used, do not spring together, although when combined as in wire-twist and stub-iron they may be considered to act as one substance, uniting the hardness of steel with, and compensating for its brittleness by, the tenacity of the soft iron. These remarks were published in 1835, and in the second work above mentioned, published in 1841, Greener states that much progress had been made in the use of steel since 'The Gun' was published; and of late years steel has been much used in rifle barrels, especially in America, where most of the rifle barrels are made from the solid bar of steel bored out. The same thing is now proposed by Mr. Burton for the military rifles, the difficulty however lies in welding on the cone seat. *Stub Damascus* is a very beautiful kind of iron formed like the Damascus iron above described, but of stub-iron instead of wire-twist, but it is open to the same objection on the ground of over-twisting.

We may here refer to a paper communicated to the Society of Arts in 1825, and published in their 'Transactions,' vol. xliii. pp. 105-108, which contains an account of the process employed at Bombay in making gun-barrels and sword-blades in imitation of those made at Damascus; from which it appears that these barrels are manufactured of iron hoops, obtained from European and chiefly from British casks. The more they are corroded by rust, the more highly are they valued; and if they are not sufficiently oxidised they are exposed to moisture until they become so. Being cut into lengths of about twelve inches, they are formed into a pile an inch or an inch and a half high, the edges being laid straight, so as not to overlap each other, and a longer piece is so fitted as to return over each end, and hold the pile together while in the fire. After being heated the pile is drawn or forged out to a bar about an inch wide and one-third of an inch thick, which is doubled up in three or more lengths, welded together, and again drawn out as before, this operation being repeated three or four times according to the degree of fineness required. The bar is then heated, a small portion at a time, and hammered on the edge so as to flatten it out the contrary way to that of the stratification, by which operation the wire or vein is brought out on the face of the strap or riband of iron. "The barrel is then forged in the usual way, but," Captain Bagnold states, "much more *jumping* is used than in the English method, in order to render the twist finer." "The most careful workmen," he adds, "always made a practice of covering the part exposed to the fire with a lute composed of mud, clay, and the dung of cows or horses, in order to guard against any unnecessary oxidation of the metal. When the barrel is complete, the twist is raised by laying the barrel from one to five days either in vinegar or a solution of the sulphate of iron, until the twist is raised; this process is called the wire-twist." "To produce the *curl*," he further states, "the bars or straps are drawn out to bars about three-quarters of an inch square, and twisted, some to the right and others to the left; one of each sort are then welded together, doubled up and drawn out as before; and upon the experience of the workman, any intricacy of twist is produced by this drawing out, doubling, and twisting." This latter process, it will be observed, resembles that of English workmen, as also does a piece of trickery which Captain Bagnold mentions, consisting in rough-filing a common English barrel, and welding a strap of Damascus iron spirally round it, or applying several such straps longitudinally, and welding them on; a fraud which must be severely condemned as impairing the barrel in a similar way to the attempted union of iron and steel above alluded to. It is important to notice, that the native Indian artists never work with coal under any consideration, but use solely charcoal from light woods. Coal, from its always containing traces of sulphur, is highly injurious to the tenacity of the iron.

Greener describes many other varieties of gun-barrel iron than are mentioned above, but these need not be further noticed, except to remark that the inferior twisted barrels are usually formed of wider rods than the better sorts, and are consequently weaker from the necessarily oblique direction of the twist, and from the circumstance that large rods do not get so thoroughly rolled as small ones, as well as from the inferior quality of the metal itself. He also describes numerous ways, often very ingenious, in which frauds are committed by unprincipled gunmakers, to avoid not only the increased cost of the superior kinds of metal, but also the increased charges for labour in almost every department upon barrels of the best quality. In some cases a strip of inferior iron will even be introduced into the heart of rods or bars of Damascus iron, by which, owing to the different expansive powers of the two metals, the gun will be impaired more than by the diminution of strength and intrinsic value.

The great amount of welding required in twisted barrels requires a very large fire, and Greener states that several hours should be spent in forging inferior barrels before the fire can be brought to a fit state for those of the best quality. Hence, he considers, the London barrel-forgers do not attain such perfection in this operation as those of Birmingham, because they do not generally make the inferior barrels necessary to bring the fire into a good state. The junction of the several lengths of rod necessary to make a twisted barrel is often effected by cutting each off in a sloping direction, and leaving them to be joined in the general welding operation; but it is better to weld them together before the twisting is completed. After welding, the barrels are re-heated to a welding heat, a few inches at a time, and hammered in a groove to the required size. Sometimes they receive a subsequent hammer-hardening in like way, when cold; but though this improves them much, it is often neglected.

After welding, the barrels are very carefully examined, and if needful, straightened by a few blows of the hammer. Holland states that their soundness is tried also, by placing one end in a bucket of water, and sucking with the mouth at the other end, until the barrel is full of water, when, if there be any crack or flaw extending through the substance of the metal, it may be detected by the appearance of moisture on the outside. They are then bored in a machine with an angular plug of tempered steel [BORING INSTRUMENTS], which is caused to revolve rapidly within the barrel, a stream of cold water being directed upon the outside to check the heat generated by the excessive friction of the tool. Greener states that the barrels are not annealed for this purpose, as Dr. Ure has represented in the 'Dictionary of Arts.' The outside of the barrel needs also to be made smooth and even, which was formerly done by applying it to the surface of a large grindstone, the workman allowing the barrel to roll slowly through his hands, so as to present every part of the surface successively to the stone; but this process is now in a great measure superseded by turning in lathes, a method which claims great economy, as well as superiority in point of accuracy, and the advantage of doing away with a most unwholesome business, and one by no means unattended with danger. In a lathe it is easy to ensure the perfect concentricity of the inner and outer surfaces of the barrel, and the perfect rotundity of the exterior surface, whereas, under the old plan of grinding, the sides of the gun were often very unequal in thickness, one side being in some instances nearly twice as thick as the other. In all cases it is advisable to forge the barrels as nearly as possible to their intended dimensions, in order that as little as possible of the surface, which has been condensed by hammering, may have to be removed. After the first or rough boring the interior is fine-bored with an instrument having but one cutting angle, which is kept to its work by strips of soft wood attached beside it. Generally speaking, barrels are bored with a perfectly equal cylindrical bore; but some gun-makers prefer enlarging the bore a little towards the breech, under the idea that the consequent contraction of the muzzle will cause the shot to fly more closely. The breech end of the barrel is then tapped with a screw-thread, to receive the breech-plug, which closes it at that end, and forms the abutment for the explosive force of the powder, and in which, in many cases, is formed the chamber to hold the powder, and the narrow passage by which that chamber is connected with the touch-hole. The best form of this chamber, and of the connection with the touch-hole, is a matter upon which gun-makers differ widely.

The barrels are then ready for *proving*, which consists in firing them in a building in which their explosion can do no harm, with a charge four or five times as great as they will have to bear when in use. A great number of barrels are fired at once, by laying them upon a strong framework of wood, with their touch-holes downwards, and connected with a train of powder which is conducted outside the building, within which is laid a heap of sand to receive the bullets. Common barrels are allowed to lie twenty-four hours in the proof-house untouched, in order that, by the action of the nitre in the gunpowder, any crack or flaw may be rendered visible. They are then carefully examined, and such as show any defect, or have bulged with the explosion, are returned to be reforged, after which they must be proved again, while such as have stood the test satisfactorily are stamped with a distinguishing mark. Notwithstanding the strict regulations which require every barrel to be thus tested, Greener thinks that in many cases the proof-mark is forged, and states that sometimes a cheat is committed by welding unproved tubes on to pistol barrels which have been proved, so as to convert them into gun-barrels, for the sake of saving the difference of a few pence in the cost of proving.

Sporting guns are very often made with two barrels fixed side by side upon one stock. Such barrels are made separately, and have their adjacent sides filed flat in order that they may lie close together. They are secured together by ribs running between them from end to end, and filling up the spandril-shaped grooves formed by their contact. For general sporting Greener says that they should not be mounted with the bores perfectly parallel with each other, but slightly converging, so that their line of fire may meet at a given distance; but opinions differ as to the best inclination or degree of convergence.

The wooden *stocks* upon which the barrel or barrels are mounted is most commonly made of walnut-tree, though bird's-eye maple and a few other woods are occasionally used. This is fitted to the barrel so accurately as to leave as little as possible to depend upon the metal fastenings by which they are connected together. Great care should be taken to adapt the weight, length, and curvature of the stock to the person for whose use it is intended. Greener observes that it is very common to make the stocks of sporting guns too short and too crooked; and Colonel Hawker, in a passage quoted by Holland, says that "the length, bend, and casting of a stock must, of course, be fitted to the shooter, who should have his measure for them as carefully entered in his gunmaker's books as that for a suit of clothes on those of his tailor." "He has then," the colonel adds, "only to direct that his guns may be well balanced, to do which the maker will introduce lead in proportion to their weight; so that, on holding each of them flat on the left hand, with the end of the feather-spring about half an inch from the little finger, he will find a sufficient equilibrium to make the gun rest perfectly steady on the hand." When the shaping of the stock is completed, it is shod with steel for fowling-pieces and rifles and brass for muskets, the trigger-guard and other metallic fittings and ornaments are let into the wood, and every part is fitted with suitable screws and fastenings, after which the whole is taken to pieces; the woodwork is finished by staining and polishing, the metalwork is filed and blued, and the barrels are sent to be finished, which is done in various ways.

When intended to be bright externally, barrels are filed all over with smooth files, and then polished with a steel burnisher. Military muskets were formerly polished in this way, but the time and labour required to maintain the polish proved so harassing during service, that the Duke of Wellington, during the Peninsular war, dispensed with it, and allowed the muskets to be browned. Of the various methods of browning or staining barrels, of which every gun-maker has his own, we may notice two, in the first of which, described by Holland, the solution employed consists of half an ounce each of nitric acid and sweet spirits of nitre, one ounce of spirits of wine, two ounces of blue vitriol, and one ounce of tincture of steel. These ingredients are mixed, the vitriol being previously dissolved in sufficient water to make, with other fluids, a quart of mixture. The barrel, being first thoroughly cleaned from grease and dirt, and having the muzzle and vent stopped up with wood, is wetted all over with this mixture, applied with a sponge or rag, and then exposed to the air for twenty-four hours, after which it is rubbed with a hard brush to remove the oxide formed on the surface. These operations may, if requisite, be repeated two or three times, until the barrel becomes perfectly brown. It is then carefully brushed, wiped and immersed in boiling water which holds a quantity of alkaline matter in solution, in order that the further action of the acid mixture may be prevented. The barrel is then dried, rubbed smooth with a burnisher of hard wood, and heated to about the temperature of boiling water, after which it is coated with a varnish composed of spirits of wine, one quart; pulverised dragon's blood, three drachms; and bruised shell-lac, one ounce. When this is dry the barrel is finally rubbed with the burnisher to give it a smooth glossy face. The second method we shall allude to is called *smoke brown* or stain, and is recommended by Greener as one of the best preventives of fraud in the manufacture of twist barrels, since it brings out the grain or pattern in a way which, to say the least, it is not easy to imitate. For producing it, the barrels are anointed with a little vitriolic acid, which is washed off, and the surface rubbed dry. A forge fire is then lighted and blown up, with coals containing as much hydrogen gas and as little sulphur as possible. When the coals are burnt until they give out a clear white flame, without any black smoke, the barrels are passed gradually backwards and forwards through the flame until they are covered with a black sooty covering. They are then placed for eighteen hours in a damp cool cellar, by which the iron particles will become coated with a red rust, while the steel retains its original sooty coat. The rust and soot being brushed off with a brush of steel wire, the barrels are washed and polished with a linen cloth dipped in water and fine washed emery, by which the two metals become very distinct, the iron being dark and the steel bright and polished. After drying, the smoking is repeated, and the barrels are left in the cellar for twelve hours, and treated as before; and thus the process is repeated until the barrel becomes as dark as may be wished, the darkest colour attainable being a fine purple-black on the iron, with a copper tinge on the steel.

The progressive steps in the invention of the fire-lock, or that contrivance attached to the breech of a gun by which the powder in the touch-hole is ignited, are noticed under ARMS. The essential qualities of a gun-lock are, first, that it should work easily and efficiently, so that the force required to move the trigger and release the spring by which the hammer, or striking part of the lock, is moved, shall not be sufficient to interfere with accuracy of aim and rapidity of firing; secondly, that it should not be liable to go off at half-cock (a position in which the lock should always be kept until actually preparing to fire, and in which even the application of force to the trigger has no effect upon it), or in any other way accidentally; and thirdly, that when the piece is on full cock, the pulling of the trigger should cause the gun to fire with certainty. The delicate workmanship of modern locks, the manufacture of which forms a distinct trade, which is carried on chiefly at and in the neighbourhood of Wolverhampton, leaves nothing to be desired in efficiency and ease of working, while the ingenuity which has been devoted to this branch of mechanical science has provided numerous admirable plans for lessening the risk of accident by means of tumblers or other contrivances for securing those parts of the lock which might occasion danger by their accidental removal. Some such contrivances, to give a fair account of which would require too much space in this article, are illustrated by

Holland, and in Dr. Ure's 'Dictionary of Arts.' Until a comparatively recent period all military guns, and most of those used for sporting purposes, were made with flint-locks, in which the ignition of the priming-powder was effected by the sudden stroke of a wedge-shaped flint against a piece of steel, by which a stream of sparks was directed into the pan containing the priming; and the greater number of flints required for this use caused the cutting, or rather breaking, of them to be a considerable branch of industry. When the first attempt was made to substitute for this contrivance the use of a fulminating or detonating powder, which, being ignited by simple percussion, should set fire to the ordinary gunpowder in the touch-hole, we are not aware; but, according to the work just referred to, the first percussion-lock was invented by the Rev. Mr. Forsyth, of Belhelvie, in Scotland. The improvement has, however, led to alterations in the construction of gun-locks which, as Holland observes, are hardly inferior to that which took place on the substitution of the modern flint for the ancient fire-match. The pan which contained the priming-powder, and the cover which shielded it until the moment of preparing to fire, are rendered unnecessary, their place being supplied by a small upright nipple, the perforation of which coincides with, and forms a continuation of, the touch-hole of the barrel. The cock, or striking part of the lock, instead of carrying a clamp to hold the flint, becomes a simple hammer, with a snout adapted to fall exactly upon the top of the nipple. The fulminating substance is usually placed, for convenience, in a small copper capsule or cap, resembling a thimble in shape, which fits on to the nipple, and, if not blown to pieces by the explosion, is removed previous to reloading. The hammer is provided with a shield to prevent any fragments of the copper cap from flying against the face of the shooter. The great superiority of the percussion principle in safety and certainty of action led to its adoption, after experiments most decisive as to its superiority, especially in wet weather, over the flint-lock, both in the arms of the British and all Continental armies. A long article relating to the compounding and use of percussion-powders made with fulminate of mercury, which forms the base of most such compositions, is given under "Fulminates," in Dr. Ure's 'Dictionary of Arts.'

Rifled guns are described under Rifle.

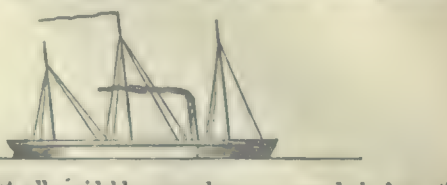
(Greener, *The Gun*, and *Treatise on Gunnery*; Holland, *Manufactures in Metal*, in Lardner's 'Cabinet Cyclopædia,' vol. ii., pp. 94-123; Barlow, *Treatise on Machinery and Manufactures*, in the 'Encyclopædia Metropolitana;' Dodd, *British Manufactures—Metals*, in Knight's 'Weekly Volume,' pp. 102-107; Dr. Ure, *Dictionary of Arts, Manufactures, and Mining*; Babbage, *Economy of Machinery and Manufactures*, sec. 362, 363.)

GUN-BOAT. This term has for many years been applied to small craft, mounting usually a single gun, when employed in the defence of coasts; and until very recently it indicated vessels of no peculiarity of construction, strength having been considered the main qualification, such as sufficient to sustain the continued working of a gun of light calibre.

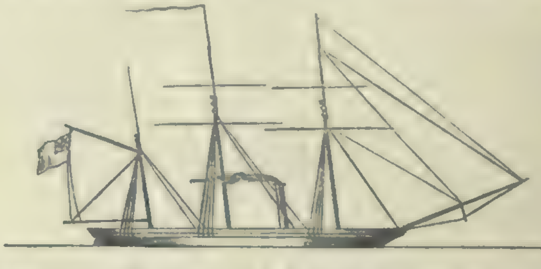
Change in naval tactics has, however, from improvements in projectiles, made such progress, that a totally new class of vessels has been called for. They are still further in request from the facilities afforded by progress in the art of propulsion. For a long period the collecting of a large number of guns in one ship had been thought the perfection of a floating battery; but the experience of the last Russian war established the importance of having a part of the armament of a fleet detached in small vessels, calculated from their light draught of water to navigate estuaries and parts of the coast which had hitherto been protected by their shallows.

Nor is it to this alone that the gun-boats of the present day owe their origin. The use of steam has so changed the features of naval warfare, that henceforward they will resemble more and more the evolutions of an army in the field; and, above all qualifications, *rapidity in manœuvring* must be paramount; and such is not so easily attained in large, long, heavily-armed ships, which, whatever may be the weight of metal thrown by their broadsides, cannot be turned to an opposite direction except within a considerable area of space and without the lapse of several minutes. Hence the attention of government has been directed to the building of the modern "gun-boat."

The ease with which a small vessel of about 100 feet length and 22 feet beam, having a light draught of about 6½ feet at the load water-line, could be manœuvred under the agency of steam as applied to the screw, even when armed with a heavy pivot-gun equal to the largest used on board the longest three-decker, was at once apparent to the Admiralty; and, accordingly, about 160 had been constructed by the beginning of 1860, 38 of them being actually on foreign service, some in the remotest parts of the globe; and before many months the number will in all exceed 200. These are generally armed with one 68-pounder gun of 95 cwt., so fitted as to be used either a-head or a-stern, or in any direction; while the vessel may be turned round almost in her own length, and in the lapse of a few seconds only. Some gun-boats have, in addition, a 32-pounder; others have two or four brass howitzers, 24-pounders. These vessels are propelled by high-pressure engines of 20, 40, or 60 horse-power. In these gun-boats, specially constructed for the purpose, and the crews of which are protected by shifting iron screen-plates from the effect of rifles, we possess a flotilla of formidable character; and as in any future naval contest these little vessels are destined evidently to play a conspicuous part, especially when armed with Armstrong's guns, we give a sketch as under. To prevent accidents from fouling the screw when dismasted, and also to prevent all avoidable encumbrance upon deck from the same cause, when in action, gun-boats are lightly rigged, have three short masts, and are fitted with gaff-sails.



A class of what may be called "despatch gun-boats," or, as they are officially called, "screw steam gun-vessels," and at present consisting of about 10 in number, are of larger dimensions, being, as the name would imply, built with capabilities for speed. They are nearly 200 feet long, and have about 30 feet beam, drawing upwards of 11 feet water, are of about 450 tons, and propelled by engines of 40, 80, and 160 horse-power. Some carry a single gun of 95 cwt., others two or four 24-pounder 12½ cwt. brass howitzers, in addition; they are rigged as three-masted two-topsail schooners. Several others, on improved principles, are now in course of building.



(Sir Howard Douglas, *On Naval Tactics*; *Screw Fleet of the Navy*, by Capt. E. P. Halsted, R.N.)

GUN-COTTON. *Pyroxylin.* If finely carded cotton be soaked for a short time in very strong nitric acid, and then washed and dried, it will be found to have acquired such powerfully explosive properties as to render it capable of being substituted for gunpowder. The cotton is not altered in appearance by this process, but its weight is increased to almost double. The reason of this increase in weight is that the elements of nitric acid (NO_5) replace, in the cotton, the elements of water (HO), the equivalent of nitric acid and of water being, as is well known, six to one; the increased weight is thus readily accounted for. The increase in weight, however, is not constant, but differs in an exact ratio with the strength of the nitric acid employed; the explosive and other properties of the resulting gun-cottons also differ considerably. In this way three, if not more, compounds may be prepared, in the first of which *three* equivalents of water, in the second *four*, and in the third *five* equivalents of water are respectively replaced by three, four, and five equivalents of nitric acid: or what is almost the same thing, only theoretically more correct, three, four, and five equivalents of hydrogen are replaced by equal numbers of equivalents of hyponitric acid (NO_4), the displaced hydrogen combining with the remaining equivalents of oxygen from the nitric acid.

Finely carded cotton has already been shown to be nearly pure cellulose [Cellulose], and, as the other varieties of cellulose are similarly acted upon by nitric acid, these explosive bodies may be viewed as nitro-substitution compounds of cellulose, and the three gun-cottons thus represented:—

Cellulose . . . . . $C_{24}H_{20}O_{20}$

No. 1. Trinitrocellulose . . . . $C_{24}\left\{\begin{matrix} H_{17} \\ (NO_4)_3 \end{matrix}\right\}O_{20}$

No. 2. Tetranitrocellulose . . . . $C_{24}\left\{\begin{matrix} H_{16} \\ (NO_4)_4 \end{matrix}\right\}O_{20}, HO$

No. 3. Pentanitrocellulose . . . $C_{24}\left\{\begin{matrix} H_{15} \\ (NO_4)_5 \end{matrix}\right\}O_{20}, 2HO$

No. 3 is very explosive, burning so rapidly when ignited, that the experiment may be performed on the palm of the hand without a sensible amount of heat being communicated to the flesh, or on a heap of gunpowder without danger of the latter being set fire to. This variety of gun-cotton is best prepared by digesting one part of cotton in fifteen parts of a mixture of equal volumes of nitric acid of sp. gr. 1·500, and of sulphuric acid of sp. gr. 1·845. The cotton must be completely immersed for about four or five minutes, and then plunged into a large quantity of cold water and washed till all trace of acid is removed: it is finally dried over a water-bath. So prepared, gun-cotton possesses an explosive power equal to three times its weight of gunpowder. Gun cotton, however, has not superseded the use of gunpowder for several reasons, the most fatal one being its liability to spontaneous ignition. From the greater rapidity of inflammation, gun-cotton also produces greater strain upon the gun, and hence necessitates increased thickness of metal. This quickness of explosion is increased to a remarkable extent by impregnating the gun-cotton with solution of chlorate of potash and then drying: on firing off a pistol loaded with two grains of gun-cotton so prepared, the barrel was shattered to pieces.

No. 1. gun-cotton is produced when acids of the strength commonly met with are used in the preparation. It is non-explosive and only partially soluble in ether containing a small per-centage of alcohol, such solution moreover leaves an opaque film on evaporation.

No. 2. is only moderately explosive, but readily dissolves in the mixture of ether and alcohol, the solution leaving on evaporation a perfectly transparent film. Hence this variety of gun-cotton is best fitted for the preparation of

Collodion.—This is the name of the solution just mentioned. It is very largely used by photographers, and is best prepared as follows:—Take of nitrate of potash, well powdered and dried, 600 grains, add to it a mixture of one and a half fluid drachms of water, and twelve fluid drachms of oil of vitriol: well stir the whole until it assumes a uniform pasty consistence, and then add in small tufts at a time, about forty grains of finely carded cotton. Let the cotton remain immersed for about ten minutes, and then wash and dry as already directed under explosive gun-cotton. If all the materials used in the process be pure, the resulting gun-cotton will be perfectly soluble in a mixture of seven parts of rectified ether, and one part of absolute alcohol, and moreover, the film of pyroxylin, left on the evaporation of the liquid from a small quantity of the collodion exposed on a glass plate, will be quite clear and transparent.

Pyroxylin balloons.—(*Collodion balloons.*)—A strong solution of collodion is made to flow evenly over the inner surface of a balloon-shaped flask, and evaporated to dryness by blowing dry air into the interior. By a little careful manipulation the pyroxylin may now be detached from the sides of the glass, and the whole drawn through the neck of the flask.

Pyroxylin balloons may be made use of for some pretty lecture illustrations with explosive gases. Thus they may be inflated with a mixture of two volumes of hydrogen, and one volume of oxygen, allowed to rise to the ceiling of a room, and there ignited. The ignition of the mixture is most conveniently effected by closing the neck of the balloon with a piece of thread impregnated with nitrate of potash, and setting fire to the thread immediately before the balloon leaves the hand.

GUN-METAL. [BRONZE.]

GUN-SHOT WOUNDS. Under this head writers on military surgery have usually considered not only all the injuries produced by cannon-balls, bullets, &c., striking against the body, but those which arise from the projection of stones, splinters of wood, and other substances broken off and thrown about by heavy balls, or by the explosion of shells, &c. We shall here include, however, only those produced by the shots themselves, because the others differ in no important degree from the more common contused wounds.

When a shot strikes the body it seldom produces much, if any immediate pain: a slight pricking sensation is felt, but the wounded man becomes aware of the injury only by his inability to move the part, or by feeling a little blood trickling over the adjacent sound skin. Whole limbs are known to have been shot off without the consciousness of the individual when in the heat of action. Sometimes when discovered the injury produces but little effect on the system: the courage and intellect remain unaffected; the pulse and respiration unaltered. Most frequently, however, if the injury be at all severe, it is followed by intense depression: the man becomes deadly pale, and is covered with profuse sweat; he trembles, and imagines death instantly at hand; he has shivering, nausea, and sickness, and remains unconscious of pain from his wound,—a sign always to be regarded with apprehension. These symptoms may soon subside if stimuli be given; but if they continue unabated for some hours they afford strong reason to fear that some important organ has been deeply injured. If the heart or the brain be struck, the man is often seen to leap from the ranks into the air and fall at once dead.

A part may suffer seriously from a shot without the skin being injured. These cases were long considered by surgeons (as they are still popularly) to be owing to the wind of the ball; that is, to the impulse of the air, set in motion and compressed by its swift passage. But the only portion of the air that could act on the body is that on one side of the ball, and this would not have much force outwards; besides, the small part of the atmosphere by the side of the ball being compressed in only one direction, while all around is free and moveable, could not acquire that degree of density necessary to produce such effects as were attributed to it. But still more certain proof that the air moved by the ball is altogether harmless, is afforded by numerous cases in which portions of dress are shot off without the parts beneath being injured. Dr. Thomson saw, after the battle of Waterloo, a man who had the tip of his nose carried off by a cannon-ball, without any further inconvenience; and another whose external ear was shot away, and his hearing not at all affected. Vacher also saw a man between whose legs a cannon-ball had passed, grazing one, and carrying off a piece of the trowsers over the other, but producing no bruise whatever. In the same manner, when a limb is shot off, the parts above the wound are but slightly injured. The real cause of this kind of injuries is, that the ball, whose force has perhaps been somewhat spent by the obstacles it has previously met with, strikes the part obliquely, and therefore with only a small part of its surface, so that the force applied is not sufficient to break through the skin, which is not only remarkably tough and elastic, but being placed on soft tissues which serve it as a kind of cushion, will yield considerably without tearing, and thus slant the ball off in another direction. The muscles and other tissues beneath it, however, being compressed between the ball and the bones, are more or less broken: there may be only a common bruise produced, but frequently the parts are found completely disorganised, broken up into a pulp with the blood effused from the vessels (often of considerable size) that have been ruptured, and sometimes even the adjacent bones are split and broken into fragments. If the ball has struck the head, or chest, or abdomen, the organs they contain may be ruptured, and give rise to such hæmorrhage or effusion of their contents as may be rapidly fatal. It was in such cases as these, when men were found lying dead in the field without any external mark of injury, that it was supposed they were suffocated by the ball passing rapidly before their mouths. If the ball penetrates the skin, a ragged opening with its edges inverted, and appearing somewhat smaller than the ball itself, is seen where it entered. The part around has a bluish or black colour from the bruise, and the cellular tissue in the track is seen black and dead. If it has struck a part perpendicularly, the ball will most likely enter into it straight; but if it have struck obliquely, it may be altogether slanted off, as in the preceding cases, or at least its course through the skin will be made more oblique, so that it will fall on the subjacent muscles at a still more acute angle than it did on the surface of the body. Its force, too, being somewhat expended, it will be the less likely to penetrate the dense fascia which usually covers them; and hence it is often found to have run for a considerable distance beneath the skin, till its force is completely spent, or till, meeting with a greater obstacle to its course onwards than outwards, it passes through the skin again, at a part considerably distant from that at which it entered. Some most remarkable cases of circuitous passages thus produced are recorded. Dr. Hennen mentions one in which the ball entered at the pomum Adami, ran completely round the neck, and was found close by the aperture at which it had penetrated; and another in which a ball struck the middle of a soldier's arm as he was climbing up a scaling-ladder, passed along the limb, over the back part of the chest, coursed along the abdominal muscles, dipped deep in the buttock, and presented at about the middle of the thigh, on the opposite side to that which it first struck. Sir C. Bell saw two cases in each of which there was one hole in the back, and another above the breast, so that externally they looked almost exactly alike; but in one case the ball, having struck obliquely, went up over the shoulder, and thence down to the breast; while in the other it had struck perpendicularly, and had gone straight through the chest. If the ball should penetrate the muscles, each layer that it meets with will render its course more oblique, till striking on the bone it may run for some distance along its surface. If it strikes very obliquely against the walls of a cavity, as the head, chest, or abdomen, its force may be so much expended in passing through them, that it may run for some distance along their concave internal surface, unable to penetrate the organs contained in them, as in cases mentioned by Dr. Hennen, where balls coursed between the peritoneum and intestines, and in one instance half round the chest between the lung and the concave surface of the walls. Similar cases are seen when the ball, striking very obliquely, does not penetrate at all, but runs for some way, even on a concave surface, between the dress and the skin, which it marks by only a slight graze. In these long or circuitous tracks, if the ball have run deep, there will be nothing to indicate the situation at which it has stopped; but when it has passed near the skin, its course will be marked by a dull bluish or dusky line, or a slight wheal. If it has passed directly into a limb, the most common situation for it to be found in is immediately beneath the skin on the opposite side; if it strike a bone, it is more likely to be arrested by its cancellous than by its compact tissue: often on passing through either its further course is prevented by the tough resisting tissue of ligaments. In almost all cases in which the ball has penetrated without passing through any part of the body, some foreign substance will be found in the track of the wound; either the shot alone, or with it portions of clothing, of the contents of the pockets, or cartridge boxes, or even (as in cases given by Dr. Hennen) of the bones of some other person whom the ball had before struck and brought along with it. Sometimes the portion of clothing carried before the ball is not perforated, but driven inwards in the form of a cul-de-sac, which may be drawn out again with the ball in it. Such a case is related where, in an attempt at suicide, a man fired a pistol close by the side of his head; the ball passed some depth into the brain, carrying the side of his night-cap before it, so that on taking it off the portion forced into the skull drew out the ball.

When the ball passes quite through the part, the aperture by which it makes its exit has characters just the reverse of those which we have mentioned as belonging to that by which it entered. Its edges are everted; it looks somewhat larger than the ball, and is less bruised. In these cases no foreign body may be found in the track of the wound, which is generally less circuitous than in the preceding class. Sometimes the ball is split by striking against the sharp edge of a bone, or obliquely on its surface; and then, while one piece passes out the other may run in any other direction among the tissues, where its presence is not likely to be suspected.

Lastly, a part of the surface, or of the whole substance of a limb, or of the trunk, may be completely shot off, either by one large ball, or by a whole charge of small shot. The surface thus left is uneven, ragged, and bruised; the vessels and nerves lie exposed, or hanging out; the bone protrudes, and is often split up, even to the next joint.

In all cases in which the ball has penetrated, the parts with which it has come in contact are so much injured that their vitality is destroyed, and sloughing to a greater or less depth ensues; to a greater distance around also all the tissues are severely bruised. The part divided presents a torn uneven surface; the vessels roughly rent across generally contract and close so that but little blood is lost at first; if a nerve be divided, unusual pain is produced, and the part is paralysed; if a bone be struck, it splinters, especially in the longitudinal direction, and is besides so shaken that death ensues in it, as in the softer tissues: after penetrating part of a bone, the ball often loses so much of its power that it remains firmly impacted in the medullary canal. If any of the cavities be penetrated, it is indicated by effusion of their contents, and other peculiar symptoms, as in the lungs by spitting up of frothy blood, extreme dyspnœa, air passing through the wound, and sometimes emphysema; in the abdomen, by protrusion of the viscera, passage of bile, fæcal matter, &c., into the cavity, producing at first extreme depression, followed by intense peritonitis.

The first process for the repair of the injury which gun-shots have occasioned is the separation of the slough or dead portion around the track of the ball. As in similar cases from common causes, the inflammation necessary for this purpose supervenes but slowly, though when established it is very intense, accompanied with great swelling, heat and pain of all the surrounding parts, and severe constitutional disturbance, fever, sleeplessness, disordered stomach, &c. As the slough separates and protrudes at the orifices of the wound, these (when double) present appearances just the reverse of those which they had when first made; that at which the ball entered (then the smallest) is now the largest, its edges are wide open, and it is generally filled with a large piece of sloughed tissue hanging from it, like tow dipped in pus; while that at which the ball passed out is contracting, or has been already healed by the first intention. This difference depends on the ball having lost much of its velocity in passing through the several tissues: hence the part last traversed is less bruised or destroyed; and if, as is often the case, the ball has been flattened in its course, it may have passed out with its sharp edge forwards, and given the latter part of the track so much the character of a common penetrating wound, that it might heal by the first intention. The constitutional symptoms change when suppuration is fairly established, the surrounding inflammation is lessened, the fever subsides, and in slight injuries the health may seem but little affected. In more severe ones, where, with considerable loss of substance, a very copious suppuration occurs, or where it involves some important tissue, as a joint or bone, &c., hectic fever supervenes, with debility, a small rapid pulse, speedy emaciation, copious night-sweats, diarrhœa, &c. A chief danger accompanying the separation of the slough is, that some of the large vessels, which, when torn by the ball, did not bleed much, if at all, may now ulcerate, and produce severe hæmorrhage; but if this be avoided, the further progress of the wound presents nothing that could distinguish it from one of the same extent produced by any penetrating instrument, and in process of being filled up by granulations.

Gun-shot wounds partake of the natures at once of penetrating, lacerating, and contused wounds, and they present the characters of all these in an extreme degree of intensity, from the velocity with which the ball, ill fitted by its shape for penetrating, has been propelled. The general rules of treatment must, however, be the same as for similar injuries from common causes; but it will be advisable here to notice a few points peculiar to this class alone, and to point out what, after long discussions, are now the most generally received rules of practice.

The extraction of the ball and other foreign substances, though its necessity has been very much exaggerated, is first to be considered. If, on examination of the wound (which should be made as much as possible with the finger), the ball and the substance it has carried in with it be felt tolerably moveable, and in a part where forceps can be easily applied, they should certainly be at once extracted; and sometimes, though very rarely, it may be advisable even to dilate the wound by incisions along its sides for this purpose. No violent attempts should ever be made at first to accomplish the removal; for as the walls of the wound slough and suppurate, the track will become larger, and they may then either fall out or be easily displaced; or they may sink down, and, presenting a dependent part, may be taken out after merely dividing the skin over them; or they may become imbedded in the surrounding tissues, and as the irritation at first produced subsides, the adhesive inflammation may form a loose sac around, in which they may lie for years, without producing any further inconvenience.

It has been already said that the ball may pass through a part, and lodge just beneath the skin of the opposite side, or that, after a circuitous course, it may be found under the skin at a distance. In either case, if it can be felt, even at the distance of an inch below the surface, it should be cut down upon and removed. If it strike against a bone, it may lodge in it superficially, and may then be displaced with the forceps or with the end of a scoop, or, if more deeply fixed, with a bullet-screw. If it pass through its wall into the cancellous texture, many surgeons recommend that the bone should be cut down upon, and a trephine applied over the ball, so as to cut out a piece of bone sufficiently large to draw it through. If the ball or other substances be not extracted at first, and remain fixed after the sloughing and suppuration, no further attempt to remove them should be made till the inflammation that has supervened is fairly subdued: then, if much irritation continues to be excited, if abscesses form about its track, and much constitutional disturbance is produced, it may be necessary to use every effort to find out their seat, and if possible remove them; but if still impracticable, and amputation cannot be performed, or is not deemed advisable, the future treatment must consist in supporting the patient by tonic and anodyne medicines, and by the mildest antiphlogistic local applications.

Whether the ball be extracted or not, the simplest possible dressings should be at first applied; a piece of linen spread with some mild ointment, fixed on lightly by strips of adhesive plaster, and covered by a rag kept constantly moist with cold water, are the best and most comfortable applications. Tight bandages, stimulating and heating ointments, &c., are especially injurious. It may be frequently advisable to bleed the patient immediately, or soon after the accident; and aperient medicine should always be given, and a mild antiphlogistic diet strictly enjoined. After three or four days, when suppuration is established, the cold application will probably cease to be agreeable to the patient, and then it should exchanged for some warm emollient poultice, or lint dipped in warm water or spongio-piline; and the constitutional disorder altering with the condition of the sore, the reducing remedies may be laid aside, and soon replaced by mild tonics, a nutritious diet, &c.

The question of amputation, when that operation is applicable, must be decided as in common cases by the character of each; no general rule can be given, except that, *cæteris paribus,* it will be advisable in many cases in military practice, in which in civil practice it would be scarcely justifiable. If the difficulty of removal from the field to any permanent hospital, the insufficiency of accommodation and nursing, which must be experienced when large numbers are simultaneously wounded, the badness of the air to which they will probably be exposed in crowded barracks, and other circumstances inseparable from the movements and arrangements of large military or naval forces, be considered, it will be evident that it would be advantageous to convert a severe wound, contused and lacerated, which even under the most favourable circumstances would be uncertain and most tedious in its progress, into a clean incised one like that of an amputation, in which danger from bleeding may be lessened and which will require far less attention than the other. As to the long-debated question, at what time amputation should be performed, it is now agreed, that the best period is as soon as possible after the patient has recovered from the immediate depressing effects which often follow the reception of the wound.

Wounds of the head, chest, and abdomen must be treated as in common cases: if the ball be lodged in these cavities, it will be improper to use more than the most gentle means to extract it; and if in the abdomen, it will generally be quite useless to search for it. The most vigorous antiphlogistic treatment will be necessary to give the patient a chance of recovery.

Secondary hæmorrhage not unfrequently ensues, when the parts around the track of the wound slough by ulceration of the larger vessels injured by the ball. The bleeding vessel must, if possible, in this case, as well as if it is observed at the first receipt of the injury, be at once cut down upon and tied both above and below the opening. In the same way, portions of various organs may slough from the injuries received, and, by giving issue to their contents, may produce rapidly fatal symptoms.

In cases where the skin is not injured, but the parts beneath greatly bruised, it is recommended to make one or more incisions in order to clear out some of the coagulated blood, &c., and to permit the discharge of the slough. Where the bones and vessels are considerably broken, as sometimes happens in these cases, amputation is at once necessary. In all cases when the sloughs have separated the wound commences to granulate, and from this time, whether its progress be towards recovery or death, its treatment need not differ from that of wounds in a similar condition from common causes.

(John Hunter, *Treatise on the Blood, Inflammation, and Gun-shot Wounds,* 'Works,' by Palmer, vol. iii., 1837; Larrey, *Mémoires de Chirurgie Militaire,* 4 vols. 8vo, 1812; Guthrie, *On Gun-shot Wounds of the Extremities,* 1 vol. 8vo, 1815; John Hennen, *Observations on some Important Points of Military Surgery,* 1 vol. 8vo, 1818.)

GUNNER, NAVAL, the highest rank in the grade of warrant officers in H.M. navy. A class of naval officers of whose multifarious duties very little is generally known, and a detailed account of which would excite surprise. It is sufficient herein to remark, that a naval gunner must of necessity be a man of considerable intelligence, as the benefits of all the evolutions necessary in the presence of an enemy would be neutralised, if he be deficient in skill, self-command, and decision. The following are some of his acquirements, duties, and responsibilities: he must, in the first place, have received a good ordinary education to enable him to pass the rigid examination expected of him. Not only is a regular course of instruction undergone on board the "Excellent" gunnery training ship, at Portsmouth, but on returning from foreign stations, and before being permitted to enter upon another ship, he is to present himself at the "Excellent," and be made proficient in any improvements in gunnery which may have been introduced during his absence. The discipline of a ship is much dependent on his judgment, forbearance and tact, and the contentment of the crew is seriously influenced more or less by the manner in which he conducts his duties, for he is the drill-master of the ship (subject in very large ships to the inspection of a gunnery-lieutenant). Assisted by his one to four or five mates, he has to instruct from 50 to 1000 men (according to the size of the ship), including the junior officers, usually styled "young gentlemen," in the great gun exercise, also with rifles, swords, pikes, and pistols; has charge of all the extensive and costly armaments and military stores, such as guns, small arms, powder, shot, shells, rockets, &c.; he is responsible for the various batteries, and that their requisites are kept at hand in convenient places, and in serviceable condition, ready for action at a moment's notice. A gunner, moreover, has charge of the magazine, and is required to be capable of working it in *total darkness;* and to be able to send up in the heat and excitement of action proper charges for certain guns, &c. He must be ready at calculation, at taking angles for ascertaining the distances of objects, and cutting his fuses accordingly with the nicest accuracy. He must have a considerable knowledge of practical geometry, to enable him to readily lay off lines for concentrating his fire, &c. He must have correct notions of laboratory work in the manufacture of the various compounds for fuses, blue lights, &c. He must keep particular accounts of his service expenditure of stores, only receiving his pay when these are approved by his commanding officers. In small vessels he keeps (with other warrant officers) a lieutenant's watch on deck, and therefore must be a thoroughly practical seaman, able to tack ship, rig and work a ship in general, for which he must have passed a severe examination by naval officers. He has constant charge of the main yard and main rigging of his ship, and also the fitting of boats for armed service. His sea-pay varies (according as he is a first, second, or third class gunner) from 120*l.* to 86*l.* per annum. He is obliged to dress (in uniform) with respectability and neatness for the sake of example. If married, the impossibility of saving money from his pay, renders his position one of some dissatisfaction in the service, and especially as the warrant officer is the only rank in the navy, from the admiral to the second class boy, which does not receive the same pay in harbour service as at sea, although his duties there are very often more harassing, and with more risk from boating, &c.; his harbour pay being, instead of 120*l.* reduced to 101*l.*, and 86*l.* reduced to 63*l.* per annum. He cannot leave the service until *entirely worn out in it,* without forfeiting all his servitude; and when pronounced by a medical survey to be unfit for further work, he can expect only a retirement of about 45*l.* per year upon the average; while if he die on service, not in action, nor suffering a violent death on active duty, there was during thirty years no provision for his widow. The widow's pension was withdrawn in 1830. The effect has, however, operated injuriously to the naval service of the country, as the emolument of gunners is considered to be so disproportionate to their responsibilities, as to have kept many good men from seeking the warrant. This is now happily under consideration; already has the Admiralty not only restored to warrant officers their rank as next to second masters, of which they were deprived in 1844; but in February, 1860, the pension to the widows of warrant officers was very considerately restored also. [BOATSWAIN.] The chief gunner's mate is a chief petty officer, and all the mates pass examination in the "Excellent."

GUNNERY is that branch of the art of war which comprehends the theory of military projectiles, and the manner of employing ordnance in the attack and defence of fortresses or positions.

Under the head of ARTILLERY will be found an account of the introduction of gunpowder for the purpose of discharging ball from cannon, and a description of the earlier forms in which they were made. Under the head of ORDNANCE is described the present construction of cannon and their weights and sizes. Representations of the forms of many ancient pieces of ordnance may be seen in the 'Treatise on Artillery,' by Diego Ufano, 1614, as well as in the 'Prattica Manuale di Artiglieria,' by Luigi Colliado, 1606. Generally the ancient fire-arms were so constructed as to discharge masses of enormous weight; and it is said, that when Mohammed II. besieged Constantinople, he employed pieces whose calibre (diameter of bore) was equal to 12 palms, and which projected against the walls of the city stones weighing 1200 lbs. At present a rapid succession of discharges from a comparatively small kind of ordnance is considered more efficacious, when directed against the walls of a fortress, than the few shots which can be fired from such unwieldy machines. The 13-inch shell which is now employed weighs, when loaded, about 200 lbs.; but when the French besieged the citadel of Antwerp in 1832, the Belgians brought up a mortar whose calibre was 24 inches, and whose shell when loaded weighed 1015 lbs. The effect produced by it was not, however, so great as had been anticipated.

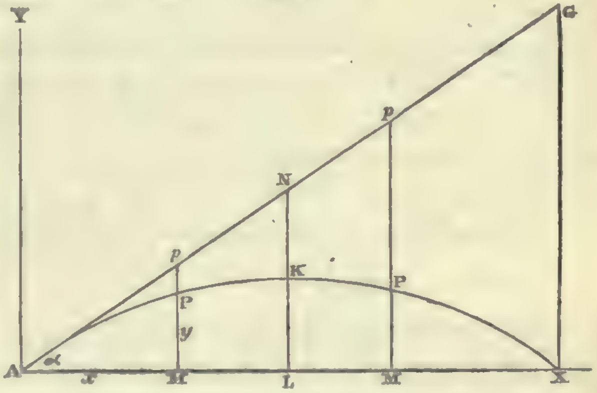
Tartalea appears to have been the first mathematician who wrote on the motion of balls when projected from fire-arms, and in his 'Quesiti et Inventione Diversi,' which was printed at Venice in 1546, he investigates a few particulars concerning that kind of motion; but the low state of the theory of such motions at that time may be imagined, when we consider that he thought it necessary to disprove the opinion, which then prevailed, that one part of the trajectory, or path, of a cannon-ball was rectilinear.

In 1638 Galileo published the 'Dialoghi delle Scienze Nuove,' in which, together with his investigations concerning the composition of motions in general, he shows that a shot projected from a gun describes a parabolic curve. He states that the shot is urged by the impulsive force of the powder in a rectilinear direction, coinciding with the axis of the bore, and that it would move with a uniform velocity if it were not continually deflected by the attraction of gravity from that direction; he shows also that this deflecting force, exerted in lines perpendicular to the horizon, would cause the shot to descend in such lines with a variable velocity. Now, the spaces which would be described in consequence of the projectile force, being proportional to the times of describing them,—and the spaces described in consequence of the earth's attraction being proportional to the squares of the times,—it followed, from the relation between the spaces so described, that the shot, which, according to the laws of the composition of motions, would always be at the intersection of the lines representing the spaces, must describe a curve with respect to which the corresponding lines would have the same relation; that is, a parabola.

Galileo expressly says that this curve would be described by the shot, if it were not resisted by the air; he was aware of that resistance, and he proposes a method of finding its effects. It is now well known that the resistance of the air, when the motion of the projectile is rapid, is such as to cause the latter to describe a curve-line very different from a parabola; and, consequently, that the parabolic theory, as it is called, is of small importance as a guide to the practical artillerist; yet, as it possesses a certain interest on account of its connection with the general subject of projectiles, and is a step to the investigation of the real trajectory, we will proceed, before entering upon that investigation, to give a demonstration of the fundamental proposition, and exhibit a few of the principal deductions which are usually made from it.

The following investigation of the curve described by the centre of gravity of a shot projected obliquely in a vacuum is extracted from Captain Boxer's 'Treatise on Artillery:'—

Fig. 1.



Let V = the initial velocity in the direction AG.

α = the angle GAX made by the direction of projection with horizontal plane.

x and y = the horizontal and vertical co-ordinates at any point P in the curve, from the point of departure A as the origin.

t = the time of flight to the point P.

AX = the whole horizontal range.

LK = the greatest height of ascent.

T = the time of flight to the point X.

Now, if no force were acting on the projectile it would, by the first law of motion, move on for ever in the line AG with the velocity V. This motion is, however, in fact modified by the action of two forces—the resistance of the atmosphere and gravity; and as it is proposed to leave the former out of consideration for the present, it only remains to compound the motion produced by gravity, which, by the second law of motion, is the same as it would produce upon a body at rest, with the uniform motion in the line AG, in order to obtain the actual motion of the shot upon the hypothesis assumed.

We have then Ap = distance described with the velocity V in the time = t = Vt.

$$x = AM = Ap \cos pAM = Vt \cos \alpha, \qquad (1)$$

$$Mp = Ap \sin pAM = Vt \sin \alpha,$$

pP = distance described from rest by the action of gravity during the time $t = \frac{1}{2} g t^2$,

$$y = MP = Mp - pP = Vt \sin \alpha - \frac{1}{2} gt \qquad (2)$$

and substituting in (2) the value of t derived from (1),

$$y=\frac{V\sin\alpha\,.\,x}{V\cos\alpha}-\tfrac{1}{2}g\frac{x^2}{V^2\cos^2\alpha}=x\tan\alpha-\frac{gx^2}{2V^2\cos^2\alpha}\qquad(3)$$

Let h represent the height which a body must fall to obtain the velocity (V), when acted upon by the force of gravity only; then

$$V^2=2gh,$$

and substituting this value in equation (3)

$$y=x\tan\alpha-\frac{x^2}{4h\cos^2\alpha}\qquad(4)$$

which is the equation to the parabola, the diameters of the curve being parallel to AY. From this equation all the properties relating to projectiles moving in a vacuum may be derived.

To find the Time of Flight.—To find the time of flight T we have

$$GX=AG\sin\alpha=VT\sin\alpha$$
$$GX=\tfrac{1}{2}gT^2$$
$$\therefore\tfrac{1}{2}gT^2=VT\sin\alpha\text{— }\therefore\text{ and }\quad T=\frac{2V\sin\alpha}{g}.\qquad(5)$$

The time of flight varies, therefore, with the sine of the angle of elevation.

The same result might also have been obtained by putting $y=o$ in equation (2).

To find the Horizontal Range.—To find the horizontal range we have,

$$AX=AG\cos\alpha$$
$$AG=VT$$
$$T=\frac{2V\sin\alpha}{g}\qquad\text{by (5)}$$
$$\therefore AX=\frac{2V^2\sin\alpha\cos\alpha}{g}$$
$$\text{or, }AX=2h\sin2\alpha,\qquad(6)$$

The same result would be obtained by putting $y=o$ in equation (3).

It appears, then, that when h, or the initial velocity, is constant, AX, or the horizontal range, varies as sine 2α; and the value of AX is greatest when $2\alpha=90$, or $\alpha=45$, in which case $AX=2h$.

Again, with the same initial velocity there are generally two angles which will give the same horizontal range. For the sine $2\alpha=\sin(108^\circ-2\alpha)$ and the ranges will be equal at equal distances from 45°.

Lastly, with the same angle of projection the initial velocities are as the square root of the ranges.

To find the greatest Height to which the Shot will Rise.—In order to find the greatest height to which the shot will rise, bisect AX in L, then $AL=L\sin2\alpha=2h\sin\alpha\cos\alpha$; and putting $ML=z$, $X=AM=2h\sin\alpha\cos\alpha\pm z$, substituting this value (3),

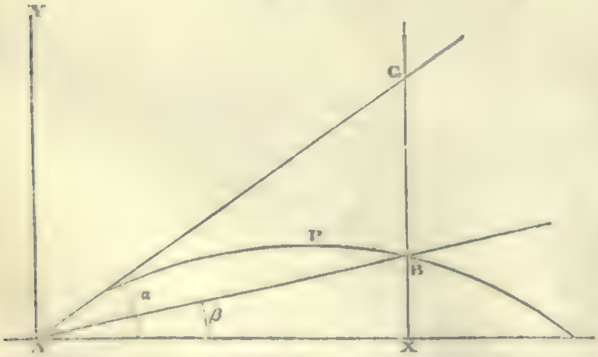
$$MP=y=(2h\sin\alpha\cos\alpha\pm z)\tan\alpha-\frac{(2h\sin\alpha\cos\alpha\pm z)^2}{4h\cos^2\alpha}$$
$$=2h\sin^2\alpha\pm z\tan\alpha-\left\{h\sin^2\alpha\pm2\tan\alpha+\frac{z^2}{4h\cos^2\alpha}\right\}$$
$$=h\sin^2\alpha-\frac{z^2}{4h\cos^2\alpha}\qquad(7)$$

MP or y has, therefore, its greatest possible value when $z=o$.

LK is therefore this greatest height, and is equal to $h\sin^2\alpha$. Equation (7) shows that the curve is symmetrical with respect to the line LK.

To find the Time of Flight, Range, &c., when the Plane is not Horizontal.—Should the line joining the object and the piece not lie in a horizontal plane, then, as the direction of the force of gravity is not perpendicular to the plane in which the gun and object are situated, the foregoing formulæ will not be applicable.

Figure 2.



Let AX represent a section of the horizontal plane, and AB that of the plane containing the gun and object B,

$$\angle GAX=\alpha$$
$$\angle BAX=\beta$$
$$T=\text{time of describing the curve }APB.$$

$$GB:AG::\sin GAB:\sin ABG$$
$$\angle GAB=(\alpha-\beta);$$
$$\angle ABG=180-\angle ABX;$$
$$\sin ABG=\sin\angle ABX=\cos\beta;$$
$$GB=\tfrac{1}{2}gT^2;\ AG=VT.$$

By substituting these values in the above proportion we have

$$\tfrac{1}{2}gT^2:VT::\sin(\alpha-\beta):\cos\beta$$
$$\tfrac{1}{2}gT^2\cos\beta=VT\sin(\alpha-\beta)$$
$$T=\frac{2V\sin(\alpha-\beta)}{g\cos\beta}\qquad(1)$$

Substituting this value of T in the equator $AG=VT$,

$$AG=\frac{2\sin(\alpha-\beta)\,v^2}{g\cos\beta}$$
$$=4h\frac{\sin(\alpha-\beta)}{\cos\beta}$$

$$\text{Also, }\sin AGB=\cos GAX=\cos\alpha$$
$$\sin ABG=\sin ABX=\cos\beta.$$

Substituting these values in the proportion

$$AB:AG::\sin AGB:\sin ABG$$

we have,

$$AB:4h\frac{\sin(\alpha-\beta)}{\cos\beta}::\cos\alpha:\cos\beta$$
$$::AB=4h\frac{\sin(\alpha-\beta).\cos\alpha}{\cos^2\beta}\qquad(2)^*$$

If the plane be a descending one, the angle β must be considered *negative.*

On the Application of the Equation to the Curve described by a Body in a Vacuum to Mortar Practice.—Although the foregoing theory will give results very different from those found in practice with shot projected with great velocities, still, for the ordinary practice with mortars, it will not be far from correct, as may be seen by an inspection of the following tables, extracted from a work entitled 'Traité de Blastique,' by M. Didion; the mortars corresponded to our 8-inch and 10-inch.

Table of Ranges calculated without taking into account the resistance of the air, and the experimental ranges:

RANGES OF SHELLS 38 CENTIMÈTRES DIAMETER.				RANGES OF SHELLS 28 CENTIMÈTRES DIAMETER.			
45° Elevation observed.	Elevation 30°.			45° Elevation observed.	Elevation 30°.		
	Observed.	Calculated.	Difference.		Observed.	Calculated.	Difference.
Mèt.	Mètres.	Mètres.	Mètres.	Mèt.	Mètres.	Mètres.	Mètres.
457	383	396	+13	343	290	298	+ 8
734	637	637	0	629	561	545	− 16
1132	980	982	+ 2	1146	1011	993	− 13
1555	1355	1350	− 5	1792	1690	1552	− 138
1757	1516	1522	+ 6				

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[*] Equations (1) and (2) may also be determined from the equations to the curve in the following manner:—

$$AB\cos\beta=x=V\cos\alpha T$$
$$AB\sin\beta=y=V\sin\alpha T-\tfrac{1}{2}gT^2$$
$$\tan\beta=\frac{y}{x}=\tan\alpha-\frac{g}{2V\cos\alpha}T$$
$$\therefore T=\frac{2V(\tan\alpha-\tan\beta)\cos\alpha}{g}\qquad(1)$$
$$=\frac{2V\sin(\alpha-\beta)}{g\cos\beta}$$

Again,

$$y=x\tan\alpha-\frac{gx^2}{2V^2\cos^2\alpha}$$
$$R\sin\beta=R\cos\beta\tan\alpha-\frac{gR^2\cos^2\beta}{2V^2\cos^2\alpha}$$
$$\frac{gR\cos^2\beta}{2V^2\cos^2\alpha}=\cos\beta\tan\alpha-\sin\beta$$
$$=\frac{\sin(\alpha-\beta)}{\cos\alpha}$$
$$R=\frac{2V^2\sin(\alpha-\beta)\cos\alpha}{g\cos^2\beta}$$
$$=\frac{4h\sin(\alpha-\beta)\cos\alpha}{\cos^2\beta}\qquad(2)$$

It appears from the latter table that up to about 1400 yards the ranges with different degrees of elevation might be calculated by the parabolic theory from the ranges for 45°, the initial velocities in the above tables having been computed from the formula

$$2\,h = \text{range with an elevation of } 45°,$$

the times of flight from the formula

$$T = \frac{\text{Range}}{V \cos a} = \frac{\text{Range}}{\sqrt{2\,gh}\,.\,\cos a}.$$

The theory of the motions of projectiles would therefore be very simple if we might neglect the effects produced by the resistance of the air during the flight of the shot; but, in fact, when high charges of powder are employed, the trajectory bears no resemblance to a parabolic curve, and can only be expressed by equations of a transcendental nature.

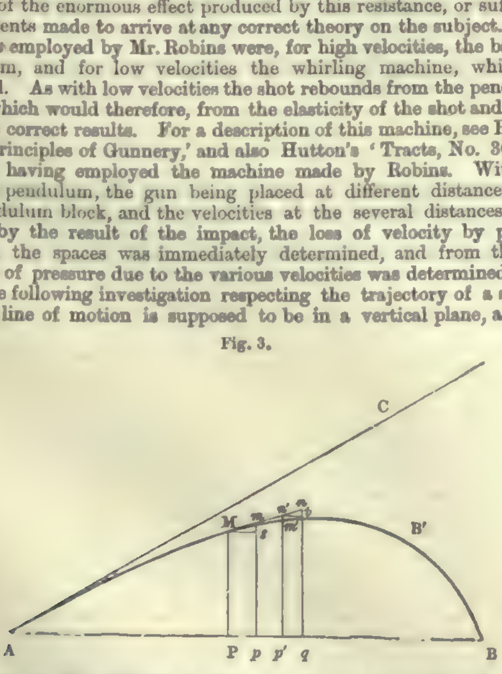
From the time of Galileo to that of Newton, though the subject of the movement of projectiles occupied the attention of nearly every mathematician in Europe, it seems to have been taken for granted that the resistance of the air was too small to deserve much consideration. Even Dr. Halley, while he admitted that its effects might become sensible when the projectile was light, conceived that it would be of no importance when the heavier kinds of shot were employed; and it is easy to conceive that the ideas then entertained of the form of the trajectory were very wide of the truth. Huygens himself, from an unfounded opinion that the resistance was proportional to the velocity simply, asserted that the path of a shot through the air was a logarithmic curve.

It was reserved for Newton to develop the true laws of the resistance experienced by bodies moving in fluid media, and to make a near approach to the form of the curve described by a projectile in the air. In a scholium to prop. 4 ('Principia,' lib. ii.), he shows that such resistance is proportional to the square of the velocity; and elsewhere he proves that, *cæteris paribus*, the resistance to globular bodies varies as the squares of their diameters and as the density of the medium. He also takes notice of the retardation which would be caused by the condensation of the fluid in front of the body when the motion is rapid, and of that produced in consequence of the air not being able to fill up immediately the partial vacuum which exists behind the ball during its flight. And, in a scholium to prop. 10, he explains that the curve described in a uniformly resisting medium is a species of hyperbola having the asymptote of the descending branch in a vertical position.

The evidence afforded by the investigations and experiments of Newton, concerning the effects produced by the resistance of the air, induced a few mathematicians to adopt in their researches the principles which he had established. Daniel Bernoulli appears to have been the first who did so; but, from an example in which he compares the ascent of a cannon-ball in the air when projected vertically upwards, with the height to which it would rise in vacuo with the same initial velocity, he has manifestly estimated the resistance much too low. And it was not till 1746, when Mr. Robins submitted a paper on the resistance of the atmosphere to the Royal Society, that any correct idea was formed of the enormous effect produced by this resistance, or sufficient experiments made to arrive at any correct theory on the subject. The methods employed by Mr. Robins were, for high velocities, the ballistic pendulum, and for low velocities the whirling machine, which he invented. As with low velocities the shot rebounds from the pendulum block, which would therefore, from the elasticity of the shot and block, not give correct results. For a description of this machine, see Robins' 'New Principles of Gunnery,' and also Hutton's 'Tracts, No. 36,' Dr. Hutton having employed the machine made by Robins. With the ballistic pendulum, the gun being placed at different distances from the pendulum block, and the velocities at the several distances determined by the result of the impact, the loss of velocity by passing through the spaces was immediately determined, and from this the amount of pressure due to the various velocities was determined.

In the following investigation respecting the trajectory of a shot in air, the line of motion is supposed to be in a vertical plane, and the resistance of the medium is supposed to vary proportionally to the square of the velocity at every point of the curve.

Fig. 3.



Let A B′ B *fig.* 3, be the curve, of which let M *m* be an indefinitely small arc described in the unit of time (as one second) in consequence of the projectile force; then, if the force of gravity and the resistance of the air were not to act on the shot, the latter might in the next equal portion of time be supposed to describe the line *m n* in the direction of a tangent to the curve at M. But, during this portion of time, let the diminution of motion caused by the resistance of the air be represented by *n n′* and the deflection produced by gravity be represented by *n′ m′*; then *m′* will be the place of the shot at the end of that portion of time. Draw the vertical lines M P, *m p*, *n′ p′*, *n q*; and the horizontal lines M *s*, *n′t*. Let A P $= x$, P M $= y$, and the arc A M $= z$; let also R represent the force of the air's resistance and g the force of gravity (both forces being measured by the velocities which they would produce, at the end of one second, in a body moving by their impulses).

Then, by the laws of motion, the velocities varying proportionally to the forces and times of motion, we have $R\,dt$ and $g\,dt$ for the resistance nn' and the force of descent nt during the evanescent portion of time expressed by dt. And by the resolution of motions $\frac{nt}{n'n}\,R\,dt$ will express the diminution of velocity vertically in consequence of the resistance, while $\frac{n't}{n'n}\,R\,dt$ will express the horizontal diminution on the same account. But from the similar triangles M*sm*, *n′tn*, we have

$n'n : n't :: Mm : ms :: dz : dy$; whence $\frac{nt}{n'n} = \frac{dy}{dz}$.

Also $n'n : n't :: Mm : Ms :: dz : dx$; whence $\frac{n't}{n'n} = \frac{dx}{dz}$.

Therefore the vertical diminution becomes $\frac{R\,dy\,dt}{dz}$; and the diminution horizontally, $\frac{R\,dx\,dt}{dz}$. To the former adding gdt for the action of gravity, as above, we have, for the whole vertical diminution of velocity, $\frac{R\,dy\,dt}{dz} + gdt$.

Now the vertical and horizontal velocities of the shot in vacuo, at M, being represented by *ms* and M*s*; that is, by $\frac{dy}{dt}$ and $\frac{dx}{dt}$ respectively: and, in the ascending branch of the trajectory the forces arising both from gravity and the resistance of the air being retardative, the velocities in the next second of time will be; in the horizontal direction $\frac{dx}{dt} - d\left(\frac{dx}{dt}\right)$, and in the vertical direction, $\frac{dy}{dt} - d\left(\frac{dy}{dt}\right)$: that is, the diminutions of velocity are, in the former direction, $-\,d\left(\frac{dx}{dt}\right)$ and, in the latter, $-\,d\left(\frac{dy}{dt}\right)$. Consequently,

$$\frac{R\,dx\,dt}{dz} = -\,d\left(\frac{dx}{dt}\right) \;.\;.\;.\;.\;.\; \text{(I)},$$

$$\text{and } \frac{R\,dy\,dt}{dz} + gdt = -\,d\left(\frac{dy}{dt}\right) \;.\;.\;.\;.\;.\; \text{(II)}.$$

But the resistance experienced by a shot moving through the air is, agreeably to the laws of hydrodynamics, represented by some part of the weight of a column of the fluid, whose base is a section through the shot perpendicular to the line of its motion, and whose height is that space through which a body would descend in vacuo to acquire the actual velocity of the shot. Therefore let A be the area of such section, v the velocity of the shot, and h the height due to that velocity; and let D be the density of the air; then $h = \frac{v^2}{2g}$ and $\frac{v^2}{2g}\,A\,.\,D =$ the weight of the column. Putting $2gp$ to represent some number which is to be determined by experiment we shall have $pv^2\,A\,.\,D$ for the resistance, or for the motion destroyed in one second, and $pv^2\,A\,.\,D\,dt$ for the motion destroyed in the time dt. But, by dynamics, $\frac{\text{momentum}}{\text{mass}} =$ velocity; therefore, if M represent the mass of the shot, $\frac{pv^2\,A\,.\,D\,dt}{M}$ is the velocity destroyed by the resistance in the time dt; and this is what is expressed above by $R\,dt$: consequently we have $R = \frac{pv^2\,A\,.\,D}{M}$; or, representing $\frac{pA\,.\,D}{M}$ by $\frac{1}{H}$, and for v putting its value $\frac{dz}{dt}$ we have $R = \frac{1}{H}\frac{dz^2}{dt^2}$. Then the general equations (I) and (II) will become

$\frac{dx\,dz}{H\,dt'} = -\,d\left(\frac{dx}{dt}\right)$ and $\frac{dy\,dz}{H\,dt} + gdt = -\,d\left(\frac{dy}{dt}\right)$; but dt being considered as constant, they may be put in the form

$$\frac{dx\,dz}{H} = -\,d^2x, \text{ and } \frac{dy\,dz}{H} + gdt^2 = -\,d^2y.$$

From the first of these equations we have $dz = -\frac{\mathrm{H}\, d^2x}{dx}$; which, being substituted in the latter, gives

$\frac{dy\, d^2z}{dx} + g dt^2 = -d^2y$; or, after reduction, $dt^2 = -d\left(\frac{dy}{dx}\right)\frac{dx}{g}$.

But, multiplying the above equation for $-d^2x$ by $\mathrm{H}\, dt^2$, it becomes $dx\, dz\, dt^2 = -\mathrm{H}\, dt^2 d^2x$; which, on substituting in the first member the preceding value of dt^2, becomes

$$dz\, d\left(\frac{dy}{dx}\right) dx^2 = \mathrm{H}\, g\, dt^2\, d^2x.$$

Again $dz = \sqrt{(dx^2 + dy^2)} = dx\sqrt{\left(1 + \frac{dy^2}{dx^2}\right)}$; therefore the last equation may be put in the form

$$dx^2\, d\left(\frac{dy}{dx}\right)\sqrt{\left(1 + \frac{dy^2}{dx^2}\right)} = \mathrm{H}\, g\, dt^2\, d^2x,$$

$$\text{or } d\left(\frac{dy}{dx}\right)\sqrt{\left(1 + \frac{dy}{dx}\right)} = \mathrm{H}\, g\, dt^2\, \frac{d^2x}{dx^3} \;.\;.\;.\;.\;.\; \text{(III)}.$$

This equation, being integrated, would determine the relation between x and y in the trajectory; and, since dt is constant, the integral of the second member is evidently, $-\frac{\mathrm{H}\, g dt^2}{2\, dx^2}$. To obtain that of the first member, let t represent the tangent of half the angle made by a horizontal line and a tangent to the curve at each point; then, by trigonometry, we shall have $\frac{dy}{dx}$ (=the tangent of the whole angle) $= \frac{2\,\mathrm{t}}{1-\mathrm{t}^2}$ and $d\left(\frac{d}{dx}\right) = \frac{2\,(1+\mathrm{t}^2)}{(1-\mathrm{t}^2)^2}\, d\,\mathrm{t}$; also $\sqrt{\left(1 + \frac{dy^2}{dx^2}\right)} = \frac{1+\mathrm{t}^2}{1-\mathrm{t}^2}$: consequently, that first member becomes $\frac{2\,(1+\mathrm{t}^2)^2\, dt}{(1-\mathrm{t}^2)^3}$, whose integral is $\frac{\mathrm{t}+\mathrm{t}^3}{(1-\mathrm{t}^2)^2} + \int\frac{d\,\mathrm{t}}{1-\mathrm{t}^2}$, or $\frac{\mathrm{t}+\mathrm{t}^3}{(1-\mathrm{t}^2)^2} + \frac{1}{2}\log.\frac{1+\mathrm{t}}{1-\mathrm{t}}$; therefore the integral of equation (III) is

$$\frac{\mathrm{t}+\mathrm{t}^3}{(1-\mathrm{t}^2)^2} + \frac{1}{2}\log.\frac{1+\mathrm{t}}{1+\mathrm{t}} = \mathrm{C} - \frac{\mathrm{H}\, g dt^2}{2\, dx^2} \;.\;.\;.\;.\;.\; \text{(IV)},$$

where C is an arbitrary constant.

Now, let E represent the angle of elevation at the point A, or the angle C A B; at this point we have $dx = dz \cos \mathrm{E}$, and $dx^2 = dz^2 \cos^2 \mathrm{E}$; also, at the same point, $ds = \mathrm{v}\, dt$, v being the initial velocity of the shot. Therefore

$dx^2 = \mathrm{v}^2\, dt^2 \cos^2 \mathrm{E}$, and $\frac{dt^2}{dx^2} = \frac{1}{\mathrm{v}^2 \cos^2 \mathrm{E}}$; but since, by dynamics, $\mathrm{v}^2 = 2g\mathrm{h}$, we have evidently,

$$\frac{dt^2}{2dx^2} = \frac{1}{4g\mathrm{h} \cos^2 \mathrm{E}};$$

then, if this value be substituted in (IV), and tan ½ E be put for t, that equation will become

$$\frac{\tan \frac{1}{2}\mathrm{E} + \tan^3 \frac{1}{2}\mathrm{E}}{(1+\tan^2 \frac{1}{2}\mathrm{E})^2} + \frac{1}{2}\log\frac{1+\tan \frac{1}{2}\mathrm{E}}{1-\tan \frac{1}{2}\mathrm{E}} = \mathrm{C} - \frac{\mathrm{H}}{2\mathrm{h}\cos^2 \mathrm{E}} \;.\;.\;.\;.\;.\; \text{(V)},$$

from whence the value of C might be found.

Substituting in the equation (IV) the above value of dt^2, viz. $-d\left(\frac{dy}{dx}\right)\frac{dx}{g}$, and putting for $\frac{dy}{dx}$ its value, $\frac{2\mathrm{t}}{1-\mathrm{t}^2}$, that equation becomes

$\frac{\mathrm{t}+\mathrm{t}^3}{(1-\mathrm{t}^2)^2} + \frac{1}{2}\log.\frac{1+\mathrm{t}}{1-\mathrm{t}} = \mathrm{C} + \frac{\mathrm{H}}{2dx}\, d\left(\frac{2\mathrm{t}}{1-\mathrm{t}^2}\right)$; whence we obtain

$$\frac{2dx}{\mathrm{H}} = -\frac{d\left(\frac{2\mathrm{t}}{1-\mathrm{t}^2}\right)}{\mathrm{C} - \frac{\mathrm{t}+\mathrm{t}^3}{(1-\mathrm{t}^2)^2} - \frac{1}{2}\log.\frac{1+\mathrm{t}}{1-\mathrm{t}}} \;.\;.\;.\;.\;.\; \text{(VI)}.$$

But, as this expression does not admit of being integrated by any known rules, mathematicians have endeavoured to obtain an approximate value of the integral; and Bezout, whose method has been adopted in the above investigation, employs the following process for that purpose. Developing the expression $\frac{1}{2}\log.\frac{1+\mathrm{t}}{1-\mathrm{t}}$ in an infinite series, putting that series in the form of a fraction, whose denominator is $(1-\mathrm{t}^2)^2$, and then substituting it in the preceding equation, the latter becomes, after reduction,

$$\frac{2dx}{\mathrm{H}} = \frac{-d\left(\frac{2\mathrm{t}}{1-\mathrm{t}^2}\right)}{\mathrm{C} - \frac{2\mathrm{t}}{1-\mathrm{t}^2}\left[1 + \frac{\frac{2}{3}\mathrm{t}^2 + \frac{4}{15}\mathrm{t}^4 + \&c.}{1-\mathrm{t}^2}\right]} \;.\;.\;.\;.\;.\; \text{(VII)}.$$

Assuming the last factor in the denominator to be constant, and representing it by b, we have

$$\frac{2dx}{\mathrm{H}} = \frac{-d\left(\frac{2\mathrm{t}}{1-\mathrm{t}^2}\right)}{\mathrm{c} - \frac{2\mathrm{t}}{1-\mathrm{t}^2}.\,\mathrm{b}} \;.\;.\;.\;.\;.\; \text{(VIII)}$$

which can easily be integrated, since the second member is equivalent to the differential of a logarithm; thus we have

$$\frac{2x}{\mathrm{H}} = \frac{1}{\mathrm{b}}\log.\left(\mathrm{c} - \frac{2\mathrm{bt}}{1-\mathrm{t}^2}\right) + \mathrm{c}' \;.\;.\;.\;.\;.\; \text{(IX)},$$

where C′ is a new arbitrary constant.

The value of b in equation (VII), when simplified, will be found to be equal to ½ sec. E + ½ cotan. E log. tan. (45° + ½ E); and Bezout has computed from this formula a table of its values for every degree of elevation. At 40° we have b = 1·1073 merely; therefore, at elevations not exceeding that number of degrees, we may, without much error, consider b as constant and equal to unity. The value of c, when obtained from equation (V) and simplified, is found to be equal to $\frac{\mathrm{H}}{4\mathrm{h}\cos \mathrm{E}} + \mathrm{b}\tan.\mathrm{E}$; and the value of C′ may be obtained by the following process.

At A, the point of projection, we have $x = 0$, and $\frac{2\mathrm{t}}{1-\mathrm{t}^2} = \tan.\mathrm{E}$; therefore, at that point, the equation (IX) becomes

$$\frac{2x}{\mathrm{H}} = \frac{1}{\mathrm{b}}\log.(\mathrm{C} - \mathrm{b}\tan.\mathrm{E}) + \mathrm{C}';$$

whence

$$\mathrm{C}' = -\frac{1}{\mathrm{b}}\log.(\mathrm{C} - \mathrm{b}\tan.\mathrm{E}), \text{ or } = -\frac{1}{\mathrm{b}}\log.\frac{\mathrm{H}}{4\mathrm{h}\cos^2 \mathrm{E}}$$

$$\text{Therefore } \frac{2x}{\mathrm{H}} = \frac{1}{\mathrm{b}}\log.\frac{4\mathrm{h}\cos^2 \mathrm{E}}{\mathrm{H}}\left(\mathrm{C} - \frac{2\mathrm{bt}}{1-\mathrm{t}^2}\right);$$

and putting e for the base of the hyperbolic logarithms (= 2·71828), we have

$$e^{\frac{2\mathrm{b}x}{\mathrm{H}}} = \frac{4\mathrm{h}\cos^2 \mathrm{E}}{\mathrm{H}}\left(\mathrm{C} - \frac{2\mathrm{bt}}{1-\mathrm{t}^2}\right) \;.\;.\;.\;.\;.\; \text{(X)},$$

$$\text{and } \frac{2\mathrm{t}}{1-\mathrm{t}^2} = \frac{1}{\mathrm{b}}\left[\mathrm{C} - \frac{\mathrm{H}}{4\mathrm{h}\cos^2 \mathrm{E}}.\, e^{\frac{2\mathrm{b}x}{\mathrm{H}}}\right].$$

But $\frac{dy}{dx} = \frac{2\mathrm{t}}{1-\mathrm{t}^2}$; therefore,

$$dy = \frac{\mathrm{C}\, dx}{\mathrm{b}} - \frac{\mathrm{H}\, dx}{4\mathrm{bh}\cos^2 \mathrm{E}}\, e^{\frac{2\mathrm{b}x}{\mathrm{H}}}.$$

This equation being integrated, and the constant determined on the supposition that $y = 0$ when $x = 0$, we have

$y = \frac{\mathrm{C}x}{\mathrm{b}} + \frac{\mathrm{H}^2}{8\mathrm{b}^2\mathrm{h}\cos^2 \mathrm{E}}\left(1 - e^{\frac{2\mathrm{b}x}{\mathrm{H}}}\right)$; or putting for C its value,

$$y = \left[\tan.\mathrm{E} + \frac{\mathrm{H}}{4\mathrm{b}^2\mathrm{h}\cos^2 \mathrm{E}}\right]x + \frac{\mathrm{H}^2}{8\mathrm{b}^2\mathrm{h}\cos^2 \mathrm{E}}\left(1 - e^{\frac{2\mathrm{b}x}{\mathrm{H}}}\right) \;.\;.\; \text{(XI)}.$$

By substituting in this equation any assumed values of x, we should obtain the corresponding vertical ordinates; and thus the form of the trajectory would be determined, approximatively. But, if the objec is merely to obtain the horizontal range, make $y = 0$ in the equation; then the latter will, after reduction, become

$$\frac{2\mathrm{b}}{\mathrm{H}}\, x\log.e = \log.\left[1 + \frac{2\mathrm{b}}{\mathrm{H}}\left(\frac{2\mathrm{bh}}{\mathrm{H}}\sin 2\mathrm{E} + 1\right)x\right].$$

Substituting in this equation different numbers for x, that which renders the two members equal to each other will express the required extent of the range.

In the preceding investigation, g has been taken to represent the accelerative force of gravity, or that by which the shot would descend in vacuo; but, in fact, it should represent the accelerative force by which the shot descends in air. And, in order to obtain the latter force, let r represent the semi-diameter of the shot, π the ratio of the circumference of a circle to its diameter (= 3·14159), D the density of the air, and D′ that of the shot. Then $\frac{4}{3}\pi r^3 \mathrm{D}'$ will express the weight of the shot in vacuo, and $\frac{4}{3}\pi r^3 \mathrm{D}$ the weight of an equal volume of air; therefore, $\frac{4}{3}\pi r^3 (\mathrm{D}' - \mathrm{D})$ is the weight of the shot in air, and $\frac{4}{3}\pi r^3 g\, (\mathrm{D}' - \mathrm{D})$ is the motive power by which the shot descends; the latter, being divided by the weight of the shot, expressed as above, gives $g\,\frac{\mathrm{D}' - \mathrm{D}}{\mathrm{D}'}$ for the accelerative power required. But if the shot be of lead or iron, whose weight far exceeds that of an equal volume of air, the term D may be considered as equal to zero, and the accelerative power may be represented by g, the force of gravity on a body in vacuo.

By differentiating the equation (XI), making $dy=o$, and, from the resulting equation, obtaining the value of x; then, on substituting this value in equation (XI), the resulting value of y would be that of the greatest vertical ordinate of the curve, while the said value of x is the corresponding abscissa.

What is called the point blank range is the distance from a point on the ground, vertically under the chamber of the gun or howitzer, to the point at which the shot strikes the ground after the discharge, the axis of the bore being supposed to be in a horizontal position, or parallel to the ground if the latter should be inclined to the horizon. The extent of such range may be determined from the equation (XI), by making $\mathrm{E}=o$ and considering y as negative. In this case the said equation becomes, b being equal to unity,

$$-y = \frac{\mathrm{H}x}{4\mathrm{h}} + \frac{\mathrm{H}^2}{8\mathrm{h}}\left(1-e^{\frac{2x}{\mathrm{H}}}\right);$$

where y is the height of the gun above the level of the spot on which the shot falls. And the equation, after reduction, becomes

$$\frac{2x}{\mathrm{H}}\ \log.\ e = \log.\frac{2\,\mathrm{H}x+\mathrm{H}^2+8\,\mathrm{h}y}{\mathrm{H}^2};$$

in which, substituting for x different assumed values, that which renders the two members equal to each other will be the required range.

The *but en blanc* of the French is frequently called the line of metal range, and signifies the distance from the chamber of the gun to the point where the trajectory of the shot crosses (the second time) a line joining the tops of the base, and muzzle rings, and produced. Here the axis of the gun, which is always a tangent to the trajectory at the nearest extremity, makes a small angle with the said line, depending on the dispart, or the difference between the semi-diameters of the gun at the base and muzzle.

Now, to find the time of flight: from the equation (IV); by reducing the logarithm to a series and proceeding as before, we shall have

$$\mathrm{H}g\ dt^2=2\,dx^2\left(c-\frac{2\mathrm{b}t}{1-t^2}\right);$$

and having found, from the equation (X), that $c-\frac{2\mathrm{b}t}{1-t^2}$ is equal to $\frac{\mathrm{H}}{4\mathrm{h}\cos^2\mathrm{E}}e^{\frac{2\mathrm{b}x}{\mathrm{H}}}$; we get

$$\mathrm{H}g\ dt^2=\frac{\mathrm{H}\ dx^2}{2\mathrm{h}\cos^2\mathrm{E}}e^{\frac{2\mathrm{b}x}{\mathrm{H}}};\ \text{or}\ dt=\frac{dx\ e^{\frac{\mathrm{b}x}{\mathrm{H}}}}{\cos\mathrm{E}\ \sqrt{2g\mathrm{h}}};$$

which being integrated gives $t=e^{\frac{\mathrm{b}x}{\mathrm{H}}}\cdot\frac{\mathrm{H}}{\mathrm{b}\cos\mathrm{E}\ \sqrt{2g\mathrm{h}}}+\mathrm{C}$, where C is an arbitrary constant.

Now, to obtain C; since t (the time of flight) $=o$ when $x=o$, by substituting those values in the equation, the latter becomes

$$o=\frac{\mathrm{H}}{\mathrm{b}\cos\mathrm{E}\ \sqrt{2g\mathrm{h}}}+\mathrm{C};\ \text{whence}\ \mathrm{C}=-\frac{\mathrm{H}}{\mathrm{b}\cos\mathrm{E}\ \sqrt{2g\mathrm{h}}}$$

and consequently $t=\frac{\mathrm{H}}{\mathrm{b}\cos\mathrm{E}\ \sqrt{2g\mathrm{h}}}\left(e^{\frac{\mathrm{b}x}{\mathrm{H}}}-1\right)$.

From which equation, on substituting the value of x (the horizontal range), which is supposed to be given, the time t of the flight of the projectile will be obtained.

It may be observed here that a knowledge of the time during which a shell will describe its trajectory is of great importance, since it enables the gunner so to regulate the length of the fuse, that the shell may explode nearly at the moment that it has reached the object which it is intended to destroy.

Note.—In determing the trajectory, the range, and the time of flight, by the above formulæ, the operations must be performed by the aid of logarithms.

It is of the first importance, in obtaining from the above formulæ a near approximation to the required values, that a correct measure of the velocity with which a shot issues from the mouth of a gun should be obtained; and the determination of such velocity, when the charge of powder is given, is the object of the following investigation, which, using the differential notation, is taken from the third volume of Dr. Hutton's Tracts.

Let r = the semi-diameter of the shot, or of the bore.
D' = the specific gravity of the shot.
$\pi = 3{\cdot}1416$ (the ratio of the circumference of a circle to its diameter).
$g = 32\frac{1}{6}$ feet.
$m = 33120$ oz. (the pressure of the atmosphere on 1 square foot).
w = the weight of the shot.
a = the distance from the bottom of the chamber to the hinder part of the ball.
b = the length of the bore.
n = the ratio of the expansive force of fired gunpowder to the pressure of the atmosphere.
v = the velocity of the shot on leaving the gun.
x = any variable distance of the shot, in the barrel, from the bottom of the chamber.
Then $r^2\pi$ = the area of a transverse section through the bore, or of a section through the shot; and
$nmr^2\pi$ = the force of the powder on the hinder part of the ball.

But the expansive force of powder being supposed to be inversely proportional to its density, or to the space which it occupies in the barrel, we have
$\frac{1}{a}:\frac{1}{x}::mnr^2\pi:\frac{mnar^2\pi}{x}$ (= the motive force of the powder at any point, in the barrel, whose distance from the bottom of the chamber $=x$).

Consequently, dividing this term by the weight of the shot, we have $\frac{mnar^2\pi}{wx}$ for the accelerative force of the powder on the shot at that point; from this term subtracting $\frac{mr^2\pi}{w}$, which expresses the retardation arising from the pressure of the atmosphere against the front of the ball while moving in the barrel, the accelerative force becomes $\frac{mr^2\pi}{w}\left(\frac{na}{x}-1\right)$; let this be represented by f. Now, by the theory of forces, we have
$vdv\ [=gfdx]=\frac{gmr^2\pi}{w}\left(\frac{nadx}{x}-dx\right)$; and the integral of this equation is

$$\tfrac{1}{2}v^2=\frac{gmr^2\pi}{w}\ (na\ \text{hyp. log.}\ x-x)+\mathrm{C};$$

where C is an arbitrary constant.

To find this constant; since $v=o$ when $x=a$, on substituting these values the equation becomes

$$o=\frac{gmr^2\pi}{w}\ (na\ \text{hyp. log.}\ a-a)+\mathrm{C};$$

from which C being found and substituted in the preceding equation, the complete integral becomes after reduction, and substituting b for x,

$$v=\sqrt{\left[\frac{2gmr^2\pi}{w}\left(na\ \text{hyp. log.}\ \frac{b}{a}+a-b\right)\right]}:$$

or substituting for w its value, namely, $\frac{4}{3}r^3\pi\,\mathrm{D}'$, we obtain for the velocity of the shot on leaving the gun,

$$v=\frac{1783}{\sqrt{r\mathrm{D}'}}\sqrt{\left(na\ \text{hyp. log.}\ \frac{b}{a}+a-b\right)}$$

On comparing the results of the formula with those obtained from experiments made with the Ballistic pendulum, Dr. Hutton found that the expansive force of powder varies, with the quantity employed, from 1776 times to 2300 times the pressure of the atmosphere; allowance being made for the loss of force occasioned by the vent and by windage. Those numbers express the values of n in the formula.

From the numerous experiments made with the machine above mentioned between the years 1784 and 1791, Dr. Hutton concludes that the initial velocities of shot are directly proportional to the square roots of the weights of the charges, and inversely proportional to the square roots of the weights of the shot (the guns being similar to each other); and he gives for the initial velocity in feet the formula $\mathrm{v}=1600\sqrt{\frac{2c}{w}}$; where c is the weight of the charge, and w that of the shot. Dr. Gregory's formula, founded on more recent experiments, is, $\mathrm{v}=1600\sqrt{\frac{3c}{w}}$, which with reduced windage is more nearly correct. It must be admitted however that some uncertainty still exists respecting the value of v, partly on account of variations in the quality of the powder, and partly in consequence of the different degrees of windage; and these are the chief causes of the want of agreement between the experimented and calculated ranges of shot. This however is not in general greater than that which has been observed between ranges obtained from different trials when made in like circumstances.

The resistances actually experienced by a shot in passing through the air were, in 1789, made the subjects of experiments with the Ballistic pendulum and the whirling machine as before mentioned, and are described in Hutton's Tracts. The resistances were determined from the general formula,

$$r=\frac{v\,v'}{32\,s}w,$$

Where r = the required resistance in pounds or ounces.
v = the mean between two velocities, namely, the first velocity and the velocity with which the ball strikes the pendulum.
v' = the difference between these velocities.
s = space passed through.
w = weight of the body in pounds or ounces.

The above formula is obtained thus, $t = \frac{3}{r}$ nearly; and $1'' : t :: 32 : 32t$ = the velocity generated or destroyed by gravity in (t) time; therefore, $32t : v' :: w : r = \frac{v'}{32t}$ but $t = \frac{s}{v}$ $\therefore r = \frac{v'v}{32s}w$ = the force of resistance. From the results of the experiments, which though not sufficient to establish a perfectly true theory, enable us to obtain results sufficiently accurate for all practical purposes, it appears that the resistances are in rather a higher ratio than the squares of the diameters of the shot; and, as examples of the amount of the resistance, it may be observed, that a ball weighing 3 lbs., when moving at the rate of 500 feet per second, was opposed by a force equal to about 35½ lbs.; and, when moving with the velocity of 1700 feet per second, by a force equivalent to the pressure of above 154 lbs. It was found also that there is a gradual increase in the exponent of the resistance as the velocity increases, probably on account of the partial vacuum behind the ball. When the motions were slowest, the resistance was nearly proportional to the square of the velocity; and when the shot moved at the rate of 1500 feet per second, that exponent seemed to have attained its maximum, the resistance being then nearly as the 2⅛ power of the velocity. Beyond that rate of motion the exponent of the resistance gradually decreased.

In the preceding formulæ the height h, or that which is due to the initial velocity, is by the theory of forces equal to $\frac{\mathrm{V}^2}{2g}$; where V represents the initial velocity, and g, as before, $= 32\frac{1}{6}$ feet. To obtain the value of H it must be observed that, from hydrostatical principles, we have $\frac{1}{2}r^2\pi p\,\mathrm{D}$ for the resistance experienced in moving through a fluid by a body which is terminated in front by a hemispherical surface; where r is the semi-diameter of the sphere, D is the specific gravity of the fluid (air in the present case), and p is a co-efficient which must be determined by experiment. Then the mass of the shot being equal to $\frac{4}{3}r^3\pi\mathrm{D}'$ (where D′ is the specific gravity of the shot), dividing the former of these terms by the latter we have $\frac{3\,\mathrm{D}p}{8\,\mathrm{D}'r}$ for the retardative power of the resistance. Hence $\sqrt{\frac{8g\,\mathrm{D}'r}{3\,\mathrm{D}p}}$ becomes the terminal, or constant velocity, with which the shot would descend in the air when the resistance of the latter becomes equal to the accelerative power of gravity.

Now, in the preceding investigations, $\frac{1}{\mathrm{H}}$ was made to represent $\frac{\mathrm{A}.\mathrm{D}p}{\mathrm{M}}$; therefore, substituting for A its equivalent $r^2\pi$, and for M its equivalent $\frac{4}{3}r^3\pi\mathrm{D}'$, we shall get $\mathrm{H} = \frac{4r\mathrm{D}'}{3\,\mathrm{D}p}$; which, being compared with the above expression for the terminal velocity, is evidently the height due to that velocity, or the space through which a body must descend from rest, *in vacuo*, to acquire that velocity.

Dr. Hutton, having formed a table exhibiting the resistances experienced by shot when moving with different velocities, determined from it, by simple proportions, the values of the terminal velocities for solid shot weighing from 1 lb. to 42 lbs. (Tract 37, art. 69.) And in the same Tract (art. 122) he has given a table of terminal velocities for several natures of shells. These last velocities necessarily differ from those of solid shot, because the shells have less weight than solid shot of equal diameters. Assuming therefore that the internal diameter is $\frac{7}{10}$ of the external diameter of a shell, he estimates the ratio of the weights of the solid and hollow shot to be as 1·42 to 1; and, in order to express the terminal velocities of the latter he diminishes those of the former in that ratio. Hence the formula for the terminal velocity of a shell should be

$$\sqrt{\frac{8gr\frac{\mathrm{D}'}{1\cdot42}}{3\,\mathrm{D}p}}, \text{ or } \sqrt{\frac{5\cdot63\,gr\mathrm{D}'}{3\,\mathrm{D}p}};$$

and from the numbers given in the tables it appears that p may be considered as equal to 0·6849. On putting this formula in numbers, r and g must be expressed in terms of the same denomination.

It is easy to conceive that by increasing the charge to a certain amount the velocity will also be increased, and that when the quantity of powder is so great that the ball is driven out of the barrel before the whole has time to act upon it, the velocity must become less. There is evidently therefore a certain quantity of powder which will produce the greatest possible velocity; and this may be determined by making the differential of the expression above found, for the velocity, equal to zero, the length a of the space occupied by the charge being considered as variable. Dr. Hutton makes the charges for producing the maximum velocity to vary with the length of the gun: thus the length of the bore being equal to 10, 20, 30, 40, and 50 calibres, the numbers 0·5, 0·81, 1·09, 1·28, and 1·43 will respectively express the weight of the powder in terms of the weight of the shot. (Tract 37, art. 189.)

The service charges, in terms of the weight of the shot, are—

For brass and iron guns . . .	$\frac{1}{3}$
For brass howitzers	$\frac{1}{6}$
For carronades	$\frac{1}{12}$

From experiments which have been carried on at Woolwich, on Sutton Heath, and in France, the following very brief abstract of the circumstances attending the flight of projectiles has been drawn up :—

I. Experiments with solid shot fired at point blank.

Iron Guns.			Brass Guns.			Carronades.		
Height of the Gun above the ground = 8 ft.			Height of the Gun above the ground = 4 ft. 6 in.			Height of the Battery above the ground = 8 ft.		
Weight of Shot in lbs.	Charge in lbs.	Range in yds.	Weight of Shot in lbs.	Charge in lbs.	Range in yds.	Weight of Shot in lbs.	Charge in lbs.	Range in yds.
68	9	360	12	4	330	68	$5\frac{11}{12}$	300
32	$10\frac{11}{16}$	420	9	3	310	42	$3\frac{1}{2}$	270
24	8	400	6	2	310	24	2	250
18	6	400	3	1	350	12	1	230

II. Ricochet practice in 1821.

Solid Shot.

Nature of Ordnance.	Elevation in degrees.	Charge.	Range in yards.	Number of grazes.
24 Pounder Iron gun	11 6 3½	8 oz. 1 lb. 2 lb.	400 600 800	18 10 8
18 Pounder Iron gun	6½ 7	9 oz. 1 lb.	400 800	27 10
12 Pounder Iron gun	6¼ 6½	6 oz. 12 oz.	400 800	19 10
68 Pounder Carronade	6¼	2 lb.	600	5
24 Pounder Brass Howitzer	4¾	1 lb.	600	2

Shells.

10 Inch iron howitzer wt. of shell 92 lbs.	5 9¾	4 lbs. 2½ lbs.	600 600	2 4
8 Inch iron howitzer wt. of shell 46 lbs.	9½ 6¾	1 lb. 2½ lbs.	400 800	12 5
5½ Inch howitzer wt. of shell 16 lbs.	9	12 oz.	600	4
24 Pounder howitzer wt. of shell 16 lbs.	4¾	9 oz.	400	16
12 Pounder howitzer wt. of shell 8 lbs.	8	oz.	600	4
68 Pounder Carronade	8½	1½ lb.	600	6

From the result of the experiments it appears that at a range of 400 yards, with a weight of powder equal to $\frac{1}{42}$ of the weight of the shot, about two-thirds of the rounds took effect: at 600 yards, with charges from $\frac{1}{33}$ to $\frac{1}{20}$, from one-half to one-third took effect; and, at 800 yards, with charges from $\frac{1}{24}$ to $\frac{1}{12}$, from one-third to two-fifths took effect. It is hence concluded that ricochet batteries should, if possible, be at distances between 400 and 600 yards from the object: at a greater distance much of the ammunition would be uselessly expended. Also that, with both shot and shells, the best elevation for enfilading a work is from 6° to 9° above the crest of the parapet of the work.

III. Practice with a 10-inch mortar, Sutton Heath, 1811. The elevation = 45° and the weight of the shell = 96 lbs.

Practice with a French 12-inch mortar, Toulon, 1830. The elevation = 45° and the weight of the shell = 162 lbs.

Charge in lbs.	Time of Flight.	Range in yards.	Charge.	Time of Flight.	Range in yards.
1 lb.	10″	448	5 lbs. 6 oz.	20″	1631
1½	12	774	10 13	28½	2579
2	16	1317	16 3	32½	3301
2½	18	1605	21 10	36½	3872
3	19	1805	27	39½	4368

The effects of shot in penetrating any material form a subject of great importance in military engineering, as a knowledge of those effects can alone afford data for constructing walls and roofs capable of resisting the momenta of the vast masses which, during a siege, may descend upon or be projected against them. And in order that such effects may be made the objects of scientific investigation, the resistance which the material opposes must be considered as a uniformly retarding force, like that which gravity would exert against a shot fired vertically upwards: then the depth penetrated will correspond to the space which would be described by a body, when subject to an accelerative force equal to that retardative force, in the time that it would acquire a velocity equal to that of the impact, and the time of the penetration may be considered as equal to that in which such velocity would be acquired. By the theorem of uniformly accelerated motions we have F varies as $\frac{w\,v^2}{s}$ (where F is the accelerative or retardative force, w is the weight of the body, v the velocity with which it is moving, and s the space moved through).

Now, if G represent the force of gravity:

g = 32⅙ feet, or the velocity generated in one second by the force of gravity,

$\frac{g}{2}$ = the space or height due to that velocity,

v = the given velocity of impact,

s = the depth of the impression. Then

$G : \frac{w\,g^2}{\frac{g}{2}} :: F : \frac{w\,v^2}{s}$; whence $F = \frac{v^2 G}{s.2g}$ which is the force of resistance exercised by the material.

If G be supposed to be equal to unity, we shall have $F = \frac{v^2}{s.2g}$ and this value of F expresses the ratio of the retardative force to that of gravity; consequently, representing the latter by the weight w of the shot, the force of resistance should be expressed by $\frac{w\,v^2}{s.2g}$.

In Sir Howard Douglas's 'Treatise on Naval Gunnery' there are recorded the following results of experiments on the penetration of an 18-pounder shot into a butt made of beams of oak; namely, with charges of 6 lbs., 3 lbs., 2½ lbs., and 1 lb., the depths of the penetrations were 42 inches, 30 inches, 28 inches, and 15 inches respectively; the velocities are 1600 feet, 1130 feet, 1024 feet, and 656 feet respectively; and from these data the mean value of F will be found to be 138701. This number expresses the resistance of the oak, in pounds, against a surface equal to the area of a section through the centre of the shot; and, by reduction, it becomes equivalent to 912190 pounds exerted on one square foot.

Similar experiments made at Metz by firing 24-pounder shot against butts of fir (the numbers being reduced to English denominations) gave 475070 pounds for the resistance exerted on a square foot.

At Woolwich, in 1835, two 24-pounder shot were fired with a velocity of 1390 feet per second against a wall of concrete, into which they penetrated to the mean depth of 3 feet 10 inches; whence, by the above formula, we have F=188047 pounds; and, consequently, the resistance on a square foot is equal to 1013730 pounds. From a like experiment made at Metz it was found that the resistance opposed by a wall of oolitic stone might be expressed by 1394800 pounds (English) on an equal surface.

The French engineers, agreeably to the theoretical determination of M. Prony, suppose the volume, instead of the depth, of the space penetrated to be proportional to the term wv^2; but when that space is cylindrical, the hypothesis will evidently be identical with that which has been above stated. Dr. Hutton finds that, on firing into wood, the depths of penetration, when high charges are employed, are in a lower ratio than the squares of the velocities, and nearly proportional to the velocities simply: this he supposes to depend on the resistance caused by the elasticity of the fibres which are driven before the ball during the time of penetration.

Mr. Robins, in his work and various tracts on gunnery, was the first to point out the important effects of rotation in producing deviations in the line of flight of cannon balls. This rotation may be caused both by the balls not fitting exactly to the bore of the gun, when the friction being greater on one side than on the other would offer a greater resistance to its motion on that side, and, secondly, by the density of the ball not being uniform. When the centres of gravity and figure do not coincide, the forces, that is, the pressure of the gases generated by the powder, acting on the ball to move it, would act unequally on each side of the centre of gravity, except when the line joining the centres of gravity and figure is coincident with the axis of the bore, and would, by the theory of parallel pressures, produce (besides exerting its whole pressure in the motion of translation in a line through the centre of gravity parallel to the axis of the bore) a motion of rotation round a horizontal axis passing through the centre of gravity, due to the couple whose arm is the line joining the centre of gravity and centre of the figure, and whose force is the same pressure acting through the centre of the figure. Though the constraint due to the bore of the gun would cause the direction of the rotation to be that in which the centre of form was moving relatively to the centre of gravity (which latter while passing through the bore must be performing equal oscillations about the centre of form in a plane containing the centre of gravity and axis of the bore) at the moment of leaving the bore, depending therefore on its length; yet as from the velocity of rotation being proportionately small to the velocity of translation, there is not time for a complete oscillation in the length of the bore, in practice the direction of rotation depends entirely on the relative positions of these points when placed in the bore of the gun. Thus, if when the ball is first acted on, the centre of gravity is in a vertical line below the centre of form, the rotation in leaving the bore will be round a horizontal axis passing through the centre of gravity, and causing the anterior part to move downwards. If the positions of the centres of gravity and form be reversed, the motion of the anterior part of the ball will be upwards, and in the same way to the right or left.

If a perfectly smooth homogeneous sphere rotate in the air, there is nothing to produce movement in the position of its centre of gravity on an axis through which it is rotating; and when rotation is combined with translation there is nothing to cause deflection from the line in which it is translated. But if the surface be not smooth, when being translated, the air being denser in front than behind, depending on the velocity of translation, the friction will not be symmetrical on both sides the axis of rotation, but being greater on the anterior surface will tend to produce deflection in the centre of the sphere in a direction contrary to the one in which this surface is moving. But on the other hand, one half of the surface is rotating in a direction *with*, and the other half in a direction *contrary to*, the motion of translation, and the actual velocity of the former half through the air being greater than that of the latter from its position, prevents its escape, and causes a greater density in the air on that side. The resistance to motion being greater in this direction than in the other, there is a tendency to produce deflection in the centre of the sphere in the direction in which the surface is rotating *contrary to* the motion of translation; that is, in the direction in which the anterior surface is rotating, and this latter tendency is found in practice to overcome the former, and the shot is deflected in the direction in which the anterior surface is rotating. When a shot is excentric, that is, where the centres of gravity and figure do not coincide, and the ball is rotating round an axis through the centre of gravity, there is not only this friction, but a displacement of air equal to the figure contained between the sphere whose radius is the shortest distance from the centre of gravity to the exterior and the figure of the shot itself. The above described effect is then immensely exaggerated; in fact, if there were no friction, the resultant normal pressures would in this case make an angle with the direction of translation, and therefore cause deflection. Experiments were made in 1851, at Shoeburyness, with shot and shell made excentric by removing portions of the metal and replacing them with a heavier or lighter body. The direction of the line joining the centre of gravity and centre of figure was then determined by floating the shot in mercury. By this means they could be strapped to wooden bottoms in any position desired. An increase of upwards of 900 yards in the range was obtained with these excentric projectiles over concentric ones at angles of 20° to 28° and 32°, and deflections proportionally large according to the relative positions of the centre of gravity and figure of the shot when placed in the bore of the gun as above described. It is evident that the deflection of spherical shot from smooth bored guns is principally, if not wholly, due to the varying rotations which arise, and which produce deflections not in planes making angles with the direction of the piece when the deflection would be proportionate to the distance, but in incurvated lines, as stated by Robins and proved by his experiment with the bent barrel. In a rifle [RIFLE] we have the means of impressing on the projectile a rotation round an axis coincident with the line of flight; when the resistances being equal round the pole of rotation, no deflection can be produced while the axis remains coincident, and any casual irregularity on the point or surface is compensated for by being constantly shifted round from one side to the other. Rifling, again, gives us the power of using elongated bullets (cylindro-conical), which are kept point foremost by their rapid rotation, which has the tendency of always keeping the axis of rotation parallel to its original direction; and it will be easily seen from the previous investigations on the resistance of the air, what a greatly increased power of maintaining its initial velocity is possessed by a ball which, with the same surface of resistance, has double or treble the weight of another. These are the reasons for the enormously increased ranges and accuracy obtained with the Whitworth and Armstrong guns, to which we shall have again occasion to refer under RIFLE.

(Colliado, *Prattica Manuale dell' Artiglieria*, Milan, 1606; Ufano, *Vraye Instruction de l'Artillerie*, Frankfort, 1614; Belidor, *Le Bombardier François*, Paris, 1731; Le Blond, *Traité de l'Artillerie*, Paris, 1748; Du Paget, *Essai sur l'Usage de l'Artillerie*, Amsterdam, 1771; Lombard, *Tables du Tir des Canons*, &c., Auxonne, 1787; D'Antoni, *On Gunpowder and Fire-arms*, translated by Capt. Thomson, London, 1789; Bezout, *Cours de Mathématiques à l'Usage du Corps d'Artillerie*, Paris, 1797; Robins, *New Principles of Gunnery*, London, 1805; Hutton, *Tracts*, London, 1812; Robison, *Mechanical Philosophy*, London, 1822; Sir Howard Douglas, *Treatise on Naval Gunnery*;

Straith, *On Fortification and Artillery*, revised by Cook and Hyde; *Treatise on Artillery for the R. M. Academy, Woolwich*, by Captain Boxer, R.A.)

GUNPOWDER, a composition with the explosive power of which every one is more or less acquainted. The date of its invention is involved in obscurity. It has been said that it was used in China as early as the year A.D. 85, and that the knowledge of it was conveyed to us from the Arabs on the return of the Crusaders to Europe; that the Arabs made use of it at the siege of Mecca in 690; and that they derived it from the Indians.

Sir George Staunton observes that "the knowledge of gunpowder in China and India seems coeval with the most distant historic events. Among the Chinese it has at all times been applied to useful purposes, as blasting rocks, &c., and in the making of fireworks; although it has not been directed through strong metallic tubes, as the Europeans did soon after they had discovered it."

Roger Bacon has been supposed to allude in an enigmatic way to the composition and explosive force of gunpowder; and about 1336 Berthold Schwartz, a monk, is said to have also discovered the mode of manufacturing it.

Gunpowder consists of a very intimate mixture of nitre, or nitrate of potash, charcoal, and sulphur. Theoretically, the proportions of these ingredients ought to be as follow:—

	Equivalent weight.	Per-centage amount.
1 equivalent nitrate of potash . .	101·11	74·8
3 equivalents carbon	18·00	13·3
1 equivalent sulphur	16·00	11·9
	135·11	100·0

It is remarkable that these proportions have been nearly attained empirically in the best descriptions of gunpowder, as seen from the following table:—

	English.	French.	Prussian.
Nitrate of potash . . .	75·0	75·0	75·0
Charcoal	15·0	12·5	13·5
Sulphur	10·0	12·5	11·5
	100·0	100·0	100·0

The suddenness and intensity of the explosion depends upon the amount of sulphur, which is on this account increased in blasting-powder, the composition of blasting-powder being:—

Nitrate of potash	65
Charcoal	15
Sulphur	20
	100

This large amount of sulphur would cause the corrosion of fire-arms, and consequently for war and sporting purposes the quantity is diminished.

The ingredients must be of the greatest attainable purity; and the nitre is fused before use, in order to expel the last portion of water, which seems however scarcely necessary for any other purpose than the exact ascertainment of its quantity, inasmuch as the mixture is subsequently wetted. The charcoal, either of alder, willow, or dog-wood, is prepared, not in the usual method, but in iron retorts; and the sulphur is the volcanic kind imported from Sicily, and is refined by melting or subliming.

When the several ingredients are prepared, they are separately ground to a fine powder, and mixed in the proper proportions. The composition is then sent to the gunpowder-mill, which consists of two stones vertically placed, and running on a bed-stone. On this bed-stone the composition is spread, and wetted with as small a quantity of water as will, together with the revolutions and weight of the runners, bring it into a proper body, but not into a paste. After the stone runners have made the proper number of revolutions over it, and it is in a fit state, it is taken off and sent to the corning-house to be corned or grained; here it is first pressed into a hard and firm body, broken into small lumps, and the powder is then grained by these lumps being put into sieves, in each of which is a flat circular piece of lignum vitæ. The sieves are made of parchment skins, having round holes punched through them; several of these sieves are fixed in a frame, which by machinery has such a motion given to it as to make the lignum vitæ runner in each sieve go round with velocity sufficient to break the lumps of powder, and force them through the sieves, forming grains of several sizes. The grains are separated from the dust by proper sieves and reels; they are then hardened, and the rougher edges taken off by being run a sufficient length of time in a close reel, which has a proper circular motion given to it.

The gunpowder, thus corned, dusted, and reeled (which is called glazing, as it puts a small degree of gloss on it), is sent to the stove and dried; care being taken not to raise the heat so as to dissipate the sulphur. The heat is regulated by a thermometer.

A powder-mill is a slight wooden building with a boarded roof. Only about 40 or 50 pounds of composition are worked at a time, as an explosion will sometimes happen from the runners and bed-stone coming in contact, and from other causes. These mills are worked by water or horses.

The theory of the action of gunpowder is this:—That particle of it on which a spark falls is immediately heated to the temperature of ignition; the nitre is decomposed, its oxygen combines with the charcoal, whilst the sulphur unites with the potassium of the nitre, thus:—

$$\underbrace{KONO_5}_{\text{Nitre.}} + S + 3C = \underbrace{KS}_{\substack{\text{Sulphide of}\\\text{potassium.}}} + N + \underbrace{3CO_2}_{\substack{\text{Carbonic}\\\text{acid.}}};$$

this combination extricates as much heat as is sufficient to inflame successively, though rapidly, the remaining mass. The cause of the expansive force of gunpowder is the production of carbonic acid and nitrogen gases; and these being liberated at a very high temperature, the effect is greatly increased. Gunpowder is thus expanded about 4000 times at the moment of explosion. According to Gay-Lussac, every 100 volumes of the gas produced consist of 53 parts of carbonic acid, 5 of carbonic oxide, and 42 of nitrogen. The carbonic oxide is formed by an excess of charcoal, as in the English powder. The solid remaining after the combustion is principally sulphuret of potassium; but it is evident that the proportions and nature both of the gaseous and solid products of the combustion must depend on the composition of the gunpowder.

Gunpowder may be fired by the electric spark, and by percussion. If it be mixed with powdered glass, or any other hard substance, and struck with a heavy hammer on an anvil, it almost always explodes. It readily burns under water, and by using a slowly burning powder, such as squibs are filled with, may be inflamed in a tube of copper, and the gaseous products of the combustion may be collected in a glass jar filled with and inverted in water in the pneumatic trough.

In ascertaining the goodness of gunpowder, which is done by determining its strength, an *eprouvette* is employed to measure its projectile force. This is a small strong barrel, in which a given quantity of the powder is fired, and the comparative expansive force is measured by the action exerted on a spring or weight.

A ready but not a very accurate way of analysing gunpowder is to wash out the nitre of a given weight by water, weigh the residue, which will show the quantity of nitre dissolved, and boil it in a solution of potash; the residue, after washing and drying, will be the charcoal, and its weight taken from that left after the action of the water will show the quantity of sulphur dissolved by the potash.

GUNTER'S LINE; GUNTER'S SCALE. [Sliding Scale.]

GUTTA-PERCHA MANUFACTURE. Few substances applicable to the arts have sprung up so rapidly into extensive use as gutta-percha. Twenty years ago it was wholly unknown in Europe. In 1842, Dr. Montgomerie, a resident at Singapore, looking at a native wood-cutter while at his employment, was struck with the peculiar appearance of the handle of the axe; it was formed of some material not familiar to him. On inquiry, Montgomerie found that the substance of which the handle was made could be moulded into any form by dipping it into boiling water until it became soft, and that it speedily resumed its tough and rigid condition when removed from the water. He next ascertained that the substance resembled caoutchouc in this: that both exude from between the bark and the wood of certain forest trees. The natives around Singapore called it by a name which, with an addition, soon became *Gutta-percha*. Dr. Montgomerie sent specimens, in various stages of preparation, to the Society of Arts in London. Independently of Dr. Montgomerie, however, a discovery of the tree and the gum was also made by Mr. Thomas Lobb, who in 1842-3 was travelling in the east as agent for Messrs. Veitch, of Exeter. Those enterprising botanists and florists employed their agent to procure new or rare plants for transmission to England; and while on his rambles, Mr. Lobb acquired a knowledge of gutta-percha, as a gum which exudes from trees. When the small pieces reached the Society of Arts, Mr. Whishaw and Mr. Hancock experimented on them, with a view to discover their useful qualities; pipes, lathe-bands, and sheets were soon produced in a rough way, and a basis was obtained for an important addition to our materials for manufactures.*

It gradually became ascertained that the gutta-percha tree abounds in the Malayan Peninsula, in Borneo, and in various islands of the Eastern Archipelago. The chiefs of those islands, or portions of them, contrive to obtain a profit out of the trade; but there is still sufficient left to allow remuneration to all else concerned. For about sixteen years the trees have eagerly been cut down as a means of obtaining the gum; and however this may be regretted as a wasteful proceeding, it nevertheless cleared the ground for future settlers in those islands. Europeans are, however, teaching the natives how to obtain the sap without cutting down the tree. The tree belongs to the *Sapotaceous* or gum-exuding group; the wood, soft and spongy, is not of much use; the fruit yields a thick oil, which the natives mix with their food, and from which an ardent spirit can be obtained. The sap, which forms the most valuable product, circulates in small vessels between the bark and the wood; by tapping, or cutting notches in the branches at certain seasons, it flows out without endangering the life of the tree. How far the process can be so managed as to obtain a continuous or periodical supply from the same tree, is a problem not yet solved. The sap flows out into vessels held underneath. Before it is consolidated by the action of the air, the gatherers knead it into lumps by the hand or by a piece of wood; it is brought into any shape at pleasure, but usually comes to market in the form of roundish lumps, eight or more inches in diameter. Most of the gutta-percha of the Eastern Archipelago comes to Singapore as the chief market; and the buyers too often find it adulterated with wood, stone, and other impurities, to increase the weight; there is also much refuse of bark, leaves, and dirt mixed up accidentally with it. On these accounts, all the specimens are narrowly scrutinised on reaching the London market, to determine their net value when freed from all impurities.

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* Credit has been given, in most of the technological and scientific publications, to Dr. Montgomerie, as the person who first introduced (in the way noticed) gutta-percha to the attention of Europeans. In 1858, however, a claim was put in for Don Jose d'Almeida; who, in 1842, bought some of the gum from the natives of Singapore, brought it to England, gave a portion to a fellow-passenger, and sent the remainder to the Royal Asiatic Society.

Before gutta-percha can be applied to any of the numerous purposes for which it is now known to be valuable, it requires a great deal of preparation. The preparatory processes are peculiar, on account of the remarkable toughness of the substance. The masses are first cut into slices, by means of a wheel provided with knives or blades; the wheel revolves two or three hundred times in a minute, and the slices are cut as if by a turnip cutter. If there are any stones or other hard impurities in the lumps, the slicing detects it; the cutting edges are blunted, and the adulterants require to be removed. The gutta-percha varies much in colour, consistency, and other qualities, even in the same mass; and a thorough mixing becomes necessary. The slices are thrown into a tank of water, heated by steam; the dirt and heavy impurities fall to the bottom, leaving the gum as a pasty mass. The gum is then transferred to a rotating machine, where sharp jagged teeth rend and tear it asunder with great violence; the fragments fall down into water, where they float. After another softening in hot water, the gutta-percha is transferred to a kneading trough; this is a kind of cylinder, kept hot, in which revolving drums knead and roll the substance most completely, rendering it as homogeneous as possible in all parts. The shapeless but purified mass is next brought into certain forms, preparatory to its useful application in the arts. These forms may be blocks, slabs, sheets, or tubes. In forming sheets, the gutta-percha is passed between steel rollers, placed at a distance apart corresponding with the thickness of the sheet to be made. By the adjustment of a few knife edges, these sheets may be cut into bands or strips of any width. In making tubes or pipes, the gutta-percha is softened, and passed through heated iron cylinders, where it is reduced to size and form by a kind of wire-drawing process.

To estimate the actual and prospective uses of this singular substance, we must take note of its properties. The toughness of gutta-percha, differing from the elasticity of caoutchouc, and the facility with which it may be softened by heat, render it fitted to receive and retain any form that may be given to it. It is very easily pressed in moulds, while in a warm and plastic state. Whether wet or dry, its uses are confined to cold purposes, as it is soon affected and thrown out of shape by heat. For many purposes, naphtha and other inflammable liquids act as cements and solvents for it. Its surface is susceptible of being so prepared as to receive paint, gilding, japanning, burnishing and other decorative modifications. Its remarkable relation to electricity renders it an invaluable substance for coating telegraphic wires. Its stubborn resistance of the corroding action of many powerful acids, alkalies, and salts, fits it for use in vessels and pipes for chemical operations. Its impermeability to water has brought it largely into use as a sheeting for damp walls and other places.

The works of the Gutta-Percha Company, in the City Road, are the largest in any country; and a list of the articles made in that establishment would show into how many departments of every-day life the use of this substance has extended. Such a list need not be given here; for every week would add something to its length; but the uses might easily, if necessary, be grouped into such headings as *domestic*, *surgical*, *chemical*, *manufacturing*, *agricultural*, *electrical*, *maritime*, *engineering*, and *ornamental*. The gutta-percha, when applied to these uses, is in form of a sheet, a strip or ribbon, a rod, a tube, a cord, a cloth, &c.; and many processes, especially stamping, are employed to fashion the gutta-percha into the desired shapes. The gum possesses much value as a material for water-pipes; it is strong and tough; it resists frost; it leaves the water as pure as it finds it; it will bear a great amount of friction and hard usage; it resists the action of marine insects; it is conveniently flexible as a material for hose for watering gardens and roads, and sprinkling malt; and it is recommended by many physicians as a substitute for lead pipes, on account of the deleterious nature of the latter. A gutta-percha tube three-quarters of an inch in diameter, and one-eighth of an inch thick, has been found to bear an internal pressure of 500 lbs. on the square inch, without bursting; it yielded a very little, and then resumed its original form. The Americans, in carrying the water of the great Croton aqueduct into New York, laid down a gutta-percha pipe, a thousand feet in length, along the bed of an intervening river, where it was kept down by anchors; the pipe bore the pressure of the aqueduct water within it and the river water around it, as well as the weight of the moorings and the friction of the bed. In a wholly different department of application, gutta-percha is singularly valuable; no other known substance equals it for *acoustic* properties. The sonorous vibrations of the air are less stifled in a gutta-percha tube than in one made of any other substance; hence the extensive use of this material for speaking-tubes, ear-trumpets, domestic telegraphs, &c.; it assists the hearing of partially-deaf persons, and transmits the sound of the voice to a distance which would otherwise render it inaudible even to sensitive ears. The electric insulating properties of gutta-percha are now well known, as among the most indispensable conditions for telegraphic communication. In land electric-telegraphs, there is no occasion to coat the copper-wires with gutta-percha, provided the supporters are made sufficiently insulating; but for the submarine wires such an envelope is necessary, to prevent the electric current from diffusing itself in the surrounding water. Wires coated with gutta-percha have also been found serviceable for igniting blasts of powder, in great engineering operations. Gunpowder has been blasted at one end of a wire 70 miles long, by a galvanic current sent in at the other end. In its form as a sheet, gutta-percha is used in many situations in contact with cold water, on account of the ease with which it can be cut and cemented, and the way in which it resists moisture. It has in this way been successfully applied as a lining for cisterns; as a material for water-buckets and valves; and as an extra sole for boots in wet weather. Some of the boats made of gutta-percha have presented very remarkable qualities. Mr. Snow, who had charge of a gutta-percha boat in the arctic ship Prince Albert, said:—"The severest trial it endured, and endured successfully, was in both my visits to Whaler Point, Port Leopold. To those unaccustomed to the nature of such ice as was there met with, it will be impossible fully to conceive the position a boat was placed in. The mere transit to and fro, among loose masses of ice, with the sea in a state of quiescence, would have been quite enough to prove the value of gutta-percha boats; but when, as in the present case, those masses were all in restless agitation, with a sea rolling in upon an opposing current, it might have been well excused—and without deteriorating from the previously-attested goodness of the article—if it had not been able to resist the severe shock it received. . . . Sliding through and over the ice; sometimes lifted completely out of the water by the sudden contact of a restless floe, and at others thrown sideways upon an adjoining craggy piece, I think it would have been next to impossible for any other kind of boat to be otherwise than crushed or stoved on the instant." The name of Gutta-Percha Inlet was given to the place where this boat had rendered such valuable service.

Widely different from any of the above-named uses, are those in which gutta-percha is employed as a material in decorative art. It is fitted for such purposes chiefly in virtue of the facility with which it takes the impress of a stamp or mould when heated, and the correctness with which it maintains that impressed form when cold. The mould may be of metal, wood, or almost any other material. One of the most frequent modes of producing the casts is this. A piece of sheet gutta-percha is laid upon a steam-heated slab of marble or stone; when sufficiently softened, it is laid upon or in the mould, a counter-mould is laid upon it, and a screw-press finishes the process. If the pattern be in very bold relief, a hydraulic-press may be necessary; but in most cases a hand-press supplies a sufficient degree of force. Some years ago the Irish Patent Office adopted gutta-percha as a material for the seals of patents, on the ground that it gives bold and sharp outlines, and is free from the odour, brittleness, and greasiness of the yellow wax previously employed; but this novelty has, we believe, not been retained by the commissioners of patents. It is by a process of pressing in moulds that a vast number of articles are made in gutta-percha, useful in their application and ornamental in their appearance. Sometimes a dextrous workman will give a clouded or grained or veined appearance, by availing himself of the different tints which different pieces of gutta-percha present; when the surface is polished, this diversity gives rise to much beauty of appearance. More closely associated with fine arts are those processes in which gutta-percha assists in a kind of engraving or transferring—for which see ENGRAVING; PRINTING; PHOTOGRAPHY.

In all that has been said hitherto concerning gutta-percha, the use of that substance by itself is implied; but much ingenuity has been displayed in producing combinations. One among the many modes of employing gutta-percha as a material for models, moulds, medallions, &c., is that of Duthoit, a French inventor. The gutta-percha is first dissolved in naphtha, then filtered, and then put into a still, with the addition of oxide of zinc, sulphate of barytes, amianthus, and one or two other substances. When the mixture has been well stirred, heat is applied, and the volatile elements driven off. The composition being taken out of the still, is ready for use. Colouring matter is either put into the still with the other ingredients, or it is mixed afterwards by masticating the composition with it, in presence of warm water containing a little soda. The substance thus prepared is suitable to make not merely models and moulded articles, but also tissues, artificial-flowers, and a substitute for leather. If diluted with naphtha or benzole, the composition may be used as a liquid paint. Some of the compositions are intended to liquefy rather than harden the gutta-percha: such as that of dissolving the gum in carburet of hydrogen, which produces a liquid useful for removing grease, making good varnish, and improving the surface of inking rollers.

Many inquiries of a peculiar character have recently been made into the properties, purity, excellences, and defects of gutta-percha, under various circumstances. The telegraphic uses of this substance are among the most important: for whether the wires pass through the sea or underground, they equally require to be protected by a covering of gutta-percha, or some other insulating substance; and it is very essential that this insulation should be proof against all the enemies who are likely to attack it. One of the important circumstances connected with the use of gutta-percha for telegraphic purposes, is the tendency of the substance to become heated when closely packed. Nearly 700 miles of coated wire were sent to India in 1853, packed in deal boxes; it was found on arrival to have been in a soft state during the voyage, allowing the wire in some places to squeeze through the gutta-percha; and also that the envelope had become rather brittle after the cooling when opened. When packed closely for some time, the substance becomes heated, absorbs twenty or more per cent. of oxygen, and is chemically an altered substance, losing much of its insulating power.

Another inquiry, connected with the telegraphic uses of gutta-percha, relates to a peculiar and little understood kind of decay to which the gum is subject, tending to destroy its useful qualities. In the autumn of 1856, some of the British Electric Telegraph Company's wires ceased to work south of Berkhampstead. Mr. Edward Highley made a careful examination of the circumstances, with a view to discover the cause. The wires were enclosed in a wooden trough or trunk, about two feet below the surface of the ground. He found that wherever the wires passed near oak-trees, the troughs and the gutta-percha were decaying; but the vicinity of other trees did not seem to produce the same injurious result. On examining more closely, he detected a whitish-looking substance, resembling the spawn of the mushroom or some other fungus; it spreads around the dead roots of the oak-trees, and around the trough, carrying decay with it; and the gutta-percha at those places was quite rotten. Portions of new trough and gutta-percha had in this way been rendered useless in the short space of six months. Under each tree was found a yellowish-green fungus, luxuriantly growing; but it was not quite apparent whether the white substance was a distinct plant, or the spawn or mycellium of the yellowish-green fungus. The subject was rightfully regarded as of much importance to the owners of subway or subterranean telegraphs; and Mr. Highley was requested to continue his investigations. During the year 1857, he exposed several specimens of sound gutta-percha to the action of the mycellium of a fungus, namely, the *Agaricus campestris*, in a bed of soil of sufficient depth; and in four months he found the gutta-percha completely eaten away.

Irrespective of all inquiries concerning the practical application of gutta-percha, are others relating to an extension of the field of supply. Already it is known that three kinds reach the market, called gutta-*percha*, gutta-*tuban*, and gutta-*girek*, differing very little in properties; and it is considered that many varieties of trees, growing in tropical countries, may probably yield a juice or sap which, carefully collected and subjected to manufacturing purposes, might weaken monopoly by extending the use and enlarging the conditions of supply. The Society of Arts, in 1852, offered a premium for the importation of any new substance which could be used as a substitute for gutta-percha. Partly arising from this offer, and partly from the natural importance of the subject, many vegetable juices have from time to time been brought under public notice. Mr. Meadows Taylor, of Hyderabad, wrote to the 'Journal of the Agricultural and Horticultural Society of India' a description of the properties of the *Muddar* plant of India, in reference to the use of its juice as a substitute for gutta-percha. Dr. Riddell, of the Nizam's army, found that the milky juice or sap of the muddar, when exposed to the air, dries tough and hard. It is a common hedge-plant, very abundant in the Nizam's dominions. In order to test the juice in various ways, Dr. Riddell collected and solidified some of it. It was found to be quite soluble in spirit of turpentine, producing a good varnish. When heated with acids, it became affected almost exactly in the same way as gutta-percha. It softened in hot water sufficiently to take the impression of a seal, and to be fashioned into cups. The natives of Rajpootana have long employed it as a waterproof varnish. The tree will grow on the poorest land, and yields a fibre available as a substitute for hemp, and therefore deserving the attention of commercial men. Still later (in 1856), Mr. Osborne, of the East India Company's Civil Service, sent to the Society of Arts specimens of desiccated juices which he had obtained from trees near Goruckpoor. When procured, the juice was nearly milk-white, with a satin-like texture; it gradually hardened in the air, and softened again in hot water. In the semi-fluid state it could be easily kneaded and extended; or used for the impression of a seal, which remains in its proper shape when cold. It effaced pencil marks, like india-rubber, but soiled the paper. The exterior became gray after a time. The gum was scarcely affected by cold water. When exposed to the flame of a candle, it melted and inflamed like sealing-wax. It dissolved completely in oil of turpentine, and then formed a good cement for uniting broken glass or china. Professor Bleekrode, connected with the Dutch colonies, published, in 1857, a full account of a Surinam tree, from which excellent gutta-percha can be obtained, or at least an exudation resembling in most of its useful properties that substance. The *Bullet-tree*, or *Gutta-percha Sapota*, as this tree is now called, is very common in groups on the hilly regions of Surinam, above the alluvial plains. When quite dry, the gum weighs about 14 per cent. of the original juice, 86 per cent. having gone off in moisture. When separated by alcohol, this gutta-percha is a beautiful substance, as white as snow. When tested in various ways with heat, ether, alcohol, chloroform, benzole, oil of turpentine, sulphuric acid, nitric acid, hydrochloric acid, ammonia, caustic potash, or caustic soda, this new substance presents all the recognised qualities of true gutta-percha.

In order to extend the present amount of knowledge concerning gutta-percha, the Society of Arts, in March, 1858, appointed a committee "to direct the institution of a series of experiments on gutta-percha, and to report from time to time such observations as may appear to elucidate the nature and cause of its decay, the different qualities of the substance, modes of detecting adulteration, and any other points valuable to the manufacturer or to those who use it." The committee consisted of eleven members, comprising the consulting engineers of two of the Electric Telegraph Companies, and several scientific men. They drew up a list of thirteen questions, relating to the decay of gutta-percha, the effects of heat and weather, the effects of age or long keeping, the best mode of joining separate pieces, the insulating properties, &c.; and another list of twelve questions, relating to the growth and trade in the article—such as the kind of trees, the season for gathering, the age of the tree, the possibility of obtaining the sap without cutting down the tree, the number and nature of the kinds known in commerce, and the possibility of cultivating gutta-percha trees in localities not at present enriched by them. These printed queries were distributed largely, with a view of obtaining information from all available quarters; and the inquiries are still going on, which this proceeding suggested.

Regarded in its commercial relations, gutta-percha manufactures have not yet become largely exported. It is comparatively a new substance, and we can easily use at home all that can be procured. The manufacturers are yearly taking out patents for the application of the gum to useful purposes. The import into the United Kingdom, in 1856, was about 16,000 cwt., worth 64,000*l.*; since which year it has considerably increased.

GUTTA SERENA is that kind of blindness which arises from derangement or disease of the nerves of the eye, whether before or after their separation from the brain. The name originated in a notion, long prevalent in the schools, that all diseases are attributable to some deleterious fluid or humour circulating in the blood or diffused in the substance of the part affected. The epithet *serene* was intended to intimate the comparative freedom from pain, and the absence of any unpleasant change in the appearance of the eye, which distinguish this class of ophthalmic complaints from others equally destructive of sight. Hence Milton, whose blindness was of this kind, thus addresses Light ('Paradise Lost,' iii. 22):—

> "But thou
> Revisit'st not these eyes that roll in vain
> To find thy piercing ray, and find no dawn;
> So thick a *drop serene* hath quenched their orbs,
> Or dim suffusion veiled:"

and in the lines to Cyriack Skinner, he notices both the external peculiarity and the cause (by far the most frequent one) of his blindness, as well as the occasional suddenness of its attack:—

> "Cyriack, *this three years' day* these eyes, *though clear*
> *To outward view of blemish or of spot,*
> Bereft of light, their seeing have forgot.
> * * * * *
> * * * What supports me, dost thou ask!
> The conscience, friend, *to have lost them overplied*
> In liberty's defence, my noble task."

But the rejection of the humoral pathology has been extended to the nomenclature derived from it; and this fanciful, though still popular term, which seems to have been devised expressly for the poets, has given place in modern systems of nosology to that of *amaurosis* (ἀμαυρος, *blind*).

The most frequent seat of the complaint is the retina; the next is probably the brain itself, or that part of the optic nerve which, lying within the cranium, is in contact or communication with the brain, and partakes of its diseases. But recent observations and experiments have proved that the affection of the optic nerve may be secondary; and that the primary seat of the disease may be in certain other nerves connected with the eye, though not immediately subservient to vision. It may likewise be symptomatic of irritation in some distant organ, probably through the intervention of the same class of nerves. The temporary failure of sight during a bilious attack is of this nature: we may also here mention once for all that the affection is sometimes merely hysterical, in which case though the blindness may be total it is rarely permanent; and the same remark may be made of a kind of amaurosis which occasionally results from the irritation of worms in the intestinal canal.

The effects of remedies and some other considerations appear to lead to the conclusion that amaurosis is generally of an inflammatory nature, or dependent at least upon a congested state of the blood-vessels. It is however unquestionably sometimes the result of an opposite state, for it may be brought on by excessive or repeated losses of blood, by long-continued nursing, and by other immoderate discharges and secretions, and is sometimes the effect of mere debility.

It may be caused by simple pressure on the optic nerve, as by the growth of a tumour, or by apoplectic effusions within the head: in this case it is analogous to the paralysis of a limb. A slight stroke received unexpectedly upon the naked eye-ball may produce it, although a violent blow when the lids are firmly closed has no such consequence. In this case it is called concussion of the retina, and is analogous to concussion of the brain. It may also be the instantaneous effect of a flash of lightning. But the most frequent causes of amaurosis are exposure of the eye to too bright a light, as in watching an eclipse of the sun; or over-exertion of it in laborious study, especially at night, or in occupations such as that of the watchmaker. The Esquimaux are very subject to this complaint from the bright reflexion of their snow-fields; and have learned by experience to guard against the danger by using snow-spectacles, which are pieces of wood pierced with small circular holes, bound before their eyes, so as to shut out a part of the field of view.

We cannot enter at length into the symptoms of amaurosis, which vary of course with the seat, the cause, and the degree of injury. The chief symptoms are a more or less rapid failure of sight, by an increasing dilution of light with darkness (if the expression may be allowed), rather than by the appearance of a cloud. Moving spots, called *muscæ volitantes*, are generally seen to flit before the eyes, especially when they are closed. There is generally some degree of pain in the organ itself, and in the forehead; when the complaint arises from exhaustion, it is felt chiefly towards the back of the head. Exertion of the sight is always fatiguing and painful. The pupil is either preternaturally large or small, and obeys the stimulus of light either not at all or very sluggishly. The eyeball is sometimes too soft; in other cases unusually firm; or it may be of the natural degree of hardness. A degree of fever is occasionally present. If one eye becomes affected, the other generally follows, especially if the cause be common to both. The complaint is most usual after the middle period of life; it is frequently found to affect members of the same family, and comes on about the same age. Dissipation of all kinds, and especially habitual inebriety, predispose to it.

Confirmed amaurosis is seldom cured; but in its early stages much may be effected by careful and skilful treatment; and the means may generally be adapted with great precision to the nature of the case, by attentive consideration of its symptoms and history.

Depletion, aperient medicines, abstinence, and a darkened chamber, must of course form a part of the treatment when the case is inflammatory: but mercury, pushed if necessary to the extent of salivation, is the remedy most to be relied on; indeed, without it, the oculist would have little chance of success in any case.

When the symptoms arise from exhaustion, an opposite plan of treatment is obviously proper; but even then the moderate action of mercury is sometimes requisite. Blisters behind the ears and between the shoulders are frequently of great service in both descriptions of cases. In *sympathetic* amaurosis the attention must of course be directed in the first place to the organ which is the original seat of irritation.

This complaint not unfrequently forms a complication of cataract and of closed pupil; probably from extension of the inflammation from the parts of the eye affected in those disorders to the choroid coat or to the retina. Operations for the cure of either of those causes of blindness would be attended with no advantage in such cases, and should not be undertaken.

GUTTURALS. [ALPHABET.]

GYMNASTICS, or more properly *gymnastic* (γυμναστική, from the word γυμνός, *naked*; it being customary among the Greeks to strip themselves, wholly or in part, before engaging in bodily exercises, and thence the word has been used to denote such exercises intended to increase health and strength). The first notice of their employment is found in the second book of the 'Iliad,' where the Grecian soldiers are described as having disembarked from the ships, and playing at quoits and javelin-hurling on the beach; and again, in the twenty-third book, Achilles is represented as instituting games in honour of Patroclus, whose funeral ceremonies had just been performed, and as bestowing rewards on the victors in chariot-races, boxing, wrestling, quoit-throwing, &c. At this time these exercises seem to have been principally practised as combining amusement with the best means of obtaining bodily strength and activity; but at a later period games were dedicated to the Gods, and, being regularly established, were conducted with the greatest ceremony; honourable rewards and civil distinctions were publicly bestowed on the conquerors, the chief of whom were deemed in no slight degree exalted above their fellow-citizens. These rewards being called *athla* (ἆθλα), gave origin to the name of *athletæ* (ἀθληταὶ,) applied to those who contended for them; a designation adopted by the Romans, and from their language introduced into our own and others of modern Europe.

It was just before the time of Hippocrates, as Plato in the third book of his 'Politeia' tells us, that gymnastic was made a part of medicine, as a means of counteracting the bad effects of increasing luxury and indolence. It was gradually reduced into a complete system: public buildings called gymnasia were erected for the purpose, and superintending officers appointed by the state. The first gymnasia were built by the Lacedæmonians (Plato, Νόμοι, lib. i.), and after them by the Athenians, who had three in the immediate neighbourhood of their city: one, called Academia, where, attracted by the pleasant walks which surrounded it, and the concourse of people of all classes who daily resorted thither, Plato was in the habit of holding his conferences with his pupils; another, named Lyceum, in which Aristotle taught; and a third, called Cynosarges, which was frequented only by the lower order. Those built by the Romans were on a more magnificent scale, and from the extensive baths which were attached to them are not unfrequently called Thermæ.

The exercises practised in the gymnasia were the following:—

Dancing, which was of various kinds. In some the movements were much like those of modern tumblers; in others, balls of various sizes were thrown about in regular time from one person to another; in others, various figures and actions were gone through in imitation of battles, sieges, &c., in which the military engaged in full armour.

Wrestling.—This, like the former, was practised alike in the gymnastics of the military, of the athletæ, and of those who merely used the exercise for the sake of health. The practice seems to have been much like that of modern wrestling.

Boxing.—The use of boxing seems to have been confined to the gymnastic practices of the military and the athletæ, for neither Galen nor any other writer on medical gymnastics recommends it. It was practised naked, either with the open or clenched hands, or with brazen or stone spheres held in them (whence σφαιρομαχεῖν), or with the cæstus, which consisted of a leathern band studded with metal knobs, wound several times round the hands and wrists. A mixed exercise of boxing and wrestling (like modern boxing) was also practised under the name of *Pancratium*, but, like the two of which it was composed, it formed no part of the medical gymnastics.

Running formed a part of all gymnastic exercises.

Leaping.—There were various kinds. Besides jumping upwards and horizontally, they used to practise springing from their knees, and with heavy weights called *haltêres* (ἁλτῆρες), which they carried in their hands, or on their heads or shoulders, or even on their feet in the form of leaden shoes.

Quoits.—This game was played by all classes. The discus or quoit was a round lens-shaped piece of stone, iron, or brass, about three or four fingers thick, and nearly a foot in diameter, which was projected under-hand. [DISCUS.] There was also an exercise similar to quoit-throwing, in which the *haltêres*, or round bars of metal, somewhat contracted in the middle, and very like a modern dumb-bell, were employed.

Hurling.—In this the dart-javelin and many other missiles were thrown over-hand, the object being, as with the quoit, to hurl to or beyond a certain distance.

In addition to these exercises, which formed the regular business of the gymnasium, and which were conducted under the especial direction of the state, numerous others were practised by the Greeks and Romans, either at their public games, or as private amusements conducive to robust health, as riding, driving, swimming, rowing, climbing of ropes, swinging, mock fights of various kinds, standing erect for a lengthened period, holding the breath, shouting, &c. The use of baths, too, formed an important part of their hygiène: they were attached to all the gymnasia, and were invariably employed after exercise. [BATH.] Various officers were appointed to conduct the exercises of the gymnasium. At Athens the chief officer was called gymnasiarchus. It was his duty to superintend the whole establishment, and all the exercises; while the xystarchus superintended the more athletic only of the exercises. There was also the gymnastes, who, being skilled in medicine, was required to prescribe the kind and extent of exercise which each was to use, and under him was the pædotribos, whose place it was to wait on those exercising, to assist and instruct them, to dispense, as Galen says, the means which the gymnastes prescribed. There were also servants set apart to each set of exercises, and for anointing, for the baths, &c.

Various causes have operated to put an end to the practice of gymnastics as a part of education and as a means of maintaining health. The present mode of warfare, in which success depends so much more on the science of the commander and the knowledge of gunnery, of fortification, and other arts, than on the physical force of each combatant, has rendered the attainment of skill in each of the branches enumerated more necessary than great bodily strength or activity, and hence among the military gymnastic exercises are almost entirely superseded. The exercises of the athletæ are indeed preserved, and the art of training is probably even better understood in the present day than it was among the ancients, though the censure which the philosophers then bestowed upon such training is just as applicable at the present day. Plato ('Politeia,' lib. 3) describes the athletæ as dull, listless, and stupid, and subject to numerous diseases, cultivating nothing but a robust body, and leaving the mind in complete neglect; and Galen ('De Morborum Temporibus') speaks of them as gluttonous and heavy, sleeping long and soundly, and seldom remaining in good condition for more than five years. The same remark might be made of the present race of pugilists, wrestlers, &c., and certainly the gymnastic exercises which form part of the system of modern training present nothing in the effects which they produce, either on the mind or body, that would make their general adoption desirable.

The same cannot be said of gymnastic exercises practised under proper control, as a means of insuring a robust habit of body, and through it a vigorous intellect, or of curing certain chronic diseases. In such estimation were they held for this purpose among the ancients, that both Plato and Aristotle thought no republic could be deemed perfect in which gymnasia were neglected as part of the national establishments; nor did they estimate their value too highly. The observation of every day plainly shows how great an influence the mind and body mutually exert on each other, and if the care and cultivation of the former be a subject deserving the especial attention of the state, the proper training of the latter should undoubtedly at the same time form a part of every system of education. It is however not only necessary that exercises or gymnastics should be a part of education, but it is also necessary to provide that the gymnastics should be proper in kind and in degree, in conformity with the judicious observations of Aristotle ('Polit.,' lib. 8).

The principle on which gymnastic exercises act is evident; their immediate effect is an increase both in the size and power of the parts exercised, in consequence of an admirable law which obtains in living bodies, that (within certain limits) in proportion to the exertion which it is required to make, a part increases not only in strength and fitness, but also in size. Instances of the application of this law may be seen daily. A person is called on to engage in some new avocation, in which muscular exertion is required, and every day he is not only improved in strength and dexterity, but the muscles brought into unusual action increase rapidly in size and vigour, so as soon to surpass those of the rest of the body which have been less employed. Nor does the beneficial influence stop here. If the exertion be not carried so far as to produce excessive fatigue, all other parts of the body sympathise with the improving condition of that which is chiefly exerted; the circulation, excited from time to time by the exercise, acquires new vigour, and the blood being thrown with unusual force into all parts of the system, all the functions are carried on with increased activity; an improvement in the general health is soon manifested; and the mind (if at the same time judiciously cultivated) acquires strength, and is rendered more capable of prolonged exertion. As instances of the bad effects of a deficiency of exercise, it will be sufficient merely to allude to the condition of those who, being compelled to a sedentary occupation during the greater part of the day, neglect to occupy a part of their leisure time in some active exertion, as walking, riding, &c.

But perhaps still more injurious effects are seen in large schools of girls, and especially in those in and about the metropolis. The fashion which prescribes a long list of so-called accomplishments as essential to the education of ladies, each of which requires a portion of the day, has left little or no time for bodily exercise of any kind; and the want of attention to this necessary condition of health has produced a great part of the diseases to which young females are subject. It would be difficult to say how else it is that the proportion of girls who are affected by curvature of the spine and other deformities is so much greater than that of boys of the same age and condition in life. Dr. Forbes ('Cyclopædia of Practical Medicine') mentions the case from his own observation of a boarding-school in which "there was not one girl who had been there two years that was not more or less crooked." He adds, "scarcely a single girl that has been at a boarding-school for two or three years returns home with unimpaired health." If the condition of boys at boarding-school be compared with this statement, the conclusion is unavoidable that the exercise allowed to young females is not only insufficient as regards the time devoted to it, but of too restrained a nature. Its ill effects indeed, when they first become evident, are very generally increased by the use of various means for supporting the parts which are supposed to be weakened, and for maintaining them in a passive condition of rest; whereas the only means by which their healthful vigour can be restored is their judicious exercise. A system of proper exercises would undoubtedly be beneficial, not only to the body, but to the mind; and the loss of the time, before devoted to study, would be fully compensated by the increase of mental activity which the pupils, healthy and robust, would then bring to their studies.

Excessive exercise, on the other hand, should be carefully avoided: for though less frequent, instances are not uncommon where undue exertion has produced effects scarcely less injurious than those which result from inactivity. The existence of either class of evils is sufficient to prove that gymnastics should form a part of the education of youth, as much as "literary instruction, music, and the art of design," which, with "gymnastic," are mentioned by Aristotle ('Polit.' lib. viii.) as the four branches of instruction recognised in his day. In order that gymnastics may produce their proper results, some general system should be established in all schools, by which one sex may be preserved from the evils of deficiency, and the other from those of excess in exertion; and the beneficial influences which gymnastics exercise on the mind as well as on the body, on the understanding and moral habits as well as on the health and strength, may be secured to both.

A desire to reunite physical with mental training is, however, now becoming prevalent, and to aid in this object the suggestions which follow are made. A description of peculiar games is scarcely required, as most readers are familiar with their characteristics. The hygienic rules are equally applicable to girls as to boys up to a certain age, and the impartial adoption of them would be a benefit to subsequent generations. A more moderate use of the sports or games is necessary for girls, on account of their greater delicacy of structure and less strength. The attempts to effect the improvement contemplated should be commenced at the earliest period after birth. In this country, young children of both sexes have long been exempted from the confinement and restraint upon the locomotive organs, as also the important vital organs seated in the chest, caused by the use of swaddling or swathing bands, still in use in the French nurseries, but recourse is had at an early period for girls to supports for the back under the name of stays or corsets, the evils resulting from which have been pointed out under the latter word [Corset]. Were the same freedom of expansion of the chest secured by the disuse of this relique of barbarism, to girls as to boys, finer figures with frequent exemption from crooked spines and consumption would be the consequence. All games which can be carried on solely, or best, in the open air, are preferable to indoor amusements. This does not depend merely on the free action of the respiration, but very much on the agency of light in promoting the changes of the molecular particles of the human frame. The utility of light in promoting salutary changes in the human frame is glanced at by Dr. Andrew Combe in his excellent work, 'Physiology Applied to Health and Education,' and in other works, but it is the subject of a highly instructive chapter in Dr. Bureaud-Riofrey's 'Education Physique des Jeunes Filles,' Paris, 1835, of which we believe there is an English version.

The propriety of conducting the education of the young as far as possible in the open air is manifest. Schools in the country, when directed by competent masters, are therefore preferable to those in towns. The alternation of bodily exercise with lessons, when circumstances allow egress into the open air, is eminently conducive to bodily development and mental energy. The system of Infant Schools, when properly carried out, goes some way to ensure these conditions. The system of Kindergartens, devised by Froebel in Germany, and introduced into England by Johan and Bertha Ronge ('A Practical Guide to the English Kindergarten,' London, 1855), has the characteristic of conducting all the movements of the body in the gymnastic exercises to the rhythm of musical sounds, but though said to have proved successful in Germany, the system does not appear likely to commend itself to English habits and modes of thought. In any system of gymnastic exercises, however, for children, it is of essential importance to provide against violent straining of the muscles, as not only may permanent injury be inflicted on the healthy by excessive efforts, or unfit postures, but where gymnastics are resorted to for the cure of distorted spines or other deformities, the evil sought to be remedied is aggravated from ignorance on the part of the superintendent. (See 'Lectures on Distortions of the Spine not connected with Caries,' by Sir B. Brodie, London, 'Medical Gazette,' January, 1849.) The same objection applies to much of the clumsy, often weighty iron apparatus employed to straighten curved spines and distorted limbs. The muscles of the back, neck and arms, judiciously brought into play, are the natural and most efficient means of correcting these deformities. The games that bring the greater number of muscles into successive or harmonious play, are the best to strengthen the system during infancy and adolescence, and to maintain it in vigour and health during manhood. A few of the most appropriate may be mentioned.

Cricket.—This game combines all the conditions stated above, as essential to healthful recreation. But to insure this, moderation in the length of time the game is pursued is above all requisite; a point apt to be neglected when victory, not health, is the object. Other games, such as foot-ball, rackets, tennis, and hand-ball, or better, battledore and shuttlecock, are healthful, and the latter, besides being most suitable for females, can be played in-doors, either in winter or during wet-weather, as a substitute for out-door exercise. Another substitute for out-door exercise for females in winter, is *Dancing*. This is undoubtedly a most wholesome exercise when enjoyed in moderation, at proper hours, and in proper places. But the dancing of fashion is most pernicious; not only from the time when engaged, turning night into day, but from its being practised in hot crowded apartments, from which the partakers issue often thoroughly exhausted, inadequately clothed, and often passing through the cold damp atmosphere of early morning to encounter its depressing effects. Professional dancers, who endeavour rather to astonish than please by their extraordinary efforts, frequently become the victims of aneurism, or heart disease, and not seldom of consumption.

The game of *Golf* as played in Scotland, and occasionally by Scotchmen in England, is a healthful recreation, and is often joined in by seniors as well as juniors. The same circumstances recommend the Scotch game of *Curling*, termed also a bonspiel, in which clergymen and grave professors unite to rival each other in dexterity in projecting a polished stone, termed a curling-stone, along the ice. This turns one of the characteristics of winter into a source of health and vigour, and counteracts the evils of a sedentary life. This is a point which deserves the greatest attention on the part of literary and professional men. The indigestion of studious persons, and clerks long confined to the desk and the counting-house, arises not so much from the exhaustion of the nervous energy, as from a deficiency of *foot-exercise.* The peculiar construction of the veins of the lower extremities, which lose the valves connected with them while passing up the limbs, the moment they enter the cavity of the abdomen, and thereby become dependent on the motion of the abdominal muscles, and those of the chest concerned in respiration, for the propulsion of the blood to the liver, there to be converted into bile, explains the injurious effects resulting from too sedentary a position. Rest and foot-exercise should be made to duly alternate; and thus the bodily powers and the proper mental energy would be ensured. The mere change of posture from sitting to standing, by reading or writing for a time in the upright position, is an advantage. Besides, for either singing or reading aloud, the erect position is the best. It is invariably observed by all the greatest singers, as allowing much fuller inspirations to be taken. Whatever increases the capacity of the chest improves the health; and the greatest attention is invariably given to this point by all skilful trainers who undertake to prepare anyone for athletic feats, whether pugilism, walking, or wrestling. Unless the candidate for such honours as the ring can bestow has good wind, or can have his breath augmented by appropriate measures, success cannot be expected. Walking some distance at a moderate pace, and running up-hill for about half a mile at the top of his speed, before breakfast, form a preliminary step of prime importance. (See Captain Barclay 'On Training in Pedestrianism,' by Walter Thom, Aberdeen, 1813.) By perseverance in these means, a comparatively feeble person may be brought up to a very high condition of bodily vigour. Such extreme measures cannot be adopted by private individuals, but the principles, properly modified, can be observed. The expansion of the chest may be accomplished by easier means. On first rising in the morning, before an open window, or better still, where there is a garden, practising drawing full breaths, at first cautiously, afterwards more freely for two, three, or ultimately ten minutes, will impart a buoyancy and elasticity which will endure throughout the day. As a means of warding off consumption, few agents are more useful (See Sir Henry Holland's 'Medical Notes and Reflections,' chapter on the Exercise of the Respiration, and art. Human Longevity, in 'Edinburgh Review,' vol. 105, p. 70.) The beneficial effects of greater expansion of the chest from the kind of occupation are shown in the observations of Dr. Guy, who found that among compositors and pressmen in printing-offices, compositors were liable to consumption in the proportion of one-fourth out of a given number of patients, while pressmen were liable in the proportion of only one-fifth. (From 'Quarterly Journal of Statistical Society,' vol. vi., pp. 197, 283, quoted by Dr. Theophilus Thompson in his 'Clinical Lectures on Pulmonary Consumption,' p. 179.) The advantage of mechanical exercise after study, is well shown in the results of the trials instituted by the Mechanical Association of Andover Theological Seminary, in the United States. (See Dr. Reynolds, 'On the Necessity of Physical Culture to Literary Men, and especially Clergymen,' reprinted from the American edition in 'The Student's Cabinet of Useful Tracts,' vol. i., p. 280, Edinburgh, 1835.) A gymnasium now exists at the University of Oxford, but whether it be resorted to by those who most need it, those most apt to be "sicklied o'er with the pale cast of thought," is doubtful. The teachers of gymnastic, or as they are termed calisthenic exercises, are often incompetent to the task, and either neglect important points, or require excessive efforts from those under their direction. Few things employed to expand the chest are more hurtful than dumb-bells. Where anything beyond the habit of drawing full breaths in the open air, as mentioned above, is required, the use of the systolic and diastolic cane, invented by Mr. Tenniel, is the best that can be resorted to. It is light, expansible, and can never overstrain the muscles of those using it. Another serviceable agent in expanding the chest is to cultivate the habit of reading aloud.

> "The poet's or historian's page, by one
> Made vocal for the amusement of the rest,"

is an exercise markedly conducive to health and happiness. In the 'Quarterly Journal of Education,' October, 1834, it is justly said: "one of the accomplishments which we wish to see cultivated among females, and which is greatly neglected or wholly overlooked, is the art of reading aloud. It is a most healthy employment when used discreetly, since exercise to the lungs is as advantageous to the lungs as to all other parts of the human frame. The ability to read aloud agreeably is also a truly domestic acquirement; it will be another link in the chain which binds men to their hearths; it will amuse the young, cheer the old, and instruct the ignorant." Where circumstances prevent the use of foot-exercise, riding on horseback comes nearest in excellence; riding in a carriage is an inferior substitute. Dr. Parry in his 'Therapeutics' observes, that if it were sufficient, it would be as reasonable to give our race-horses an airing on the backs of elephants; they would then have small chance of winning in the contest. Swimming is among the most healthful of recreations when nothing forbids its use, such as great delicacy, [Bathing] tendency to fits or other spasmodic diseases, or diseased heart or lungs. Rowing, when restrained to proper limits, is useful, but exercises the upper extremities to excess and stints the lower. The Thames watermen were striking instances of unequal development of the frame. Skating, when not too prolonged, is, apart from the risk of accidents, a highly salutary recreation.

Bacon, Milton, Locke, the greatest authorities on education among the moderns, are unanimous in commending out of door exercise as constituting a portion of scholastic discipline. Milton enforces it thus: "Besides these constant exercises at home, there is another opportunity of gaining experience to be won from pleasure itself abroad; in those vernal seasons of the year, when the air is calm and pleasant, it were an injury and sullenness against Nature, not to go out and see her riches, and partake in her rejoicing between heaven and earth." Tractate, 'on Education,' § 22. But all writers with uniform consent admit,—

> "That he whom toil hath braced, or manly play,
> Has light as air each limb, each thought as clear as day."
>
> *Castle of Indolence.*

(Strutt's *Sports and Pastimes of the People of England*, 8vo, London, 1831. Dr. Andrew Combe, *The Principles of Physiology applied to the preservation of Health.* Dr. Southwood Smith's *Philosophy of Health;* and *The Laws of Life, with special reference to the Physical Education of Girls*, by Elizabeth Blackwell, M.D., English ed., 1859.)

GYPSIES, a word corrupted from Egyptians, is the name given in England to a wandering race of people who are found scattered over many countries of Europe, whither they migrated from the East about the beginning of the 15th century. Pasquier, in his 'Recherches Historiques,' says that they first appeared at Paris in the character of penitents, or pilgrims, in August, 1427, in a troop of more than 100, under some chiefs who styled themselves counts, and that they represented themselves as Christians driven out of Egypt by the Mussulmans. They obtained permission to remain in the kingdom; other troops followed, and they wandered about in all directions, unmolested for many years, committing petty depredations, and their women assuming the calling of fortune-tellers. In 1560 an ordonnance of the states of Orléans enjoined all impostors and vagabonds styled "Bohemians," or "Egyptians," to quit the kingdom under pain of the galleys. The name of Bohemians, given to them by the French, may be owing to the circumstance of some of them having come to France from Bohemia, for they are mentioned as having appeared in various parts of Germany previous to their entering France; others derive the word from "Boëm," an old French word signifying a sorcerer. (Moreri, art. "Bohemiens;" and Ducange's 'Glossary,' art. "Ægyptiaci.") The Germans gave them the name of "Zigeuner," or wanderers; the Russians, "Zigani;" the Turks and Persians, "Zingarri;" the Dutch called them "Heiden," or heathens; the Danes and Swedes, "Tartars." In Italy they are called "Zingari;" in Turkey and the Levant, "Tchingenes;" in Spain they are called "Gitanos," or "Zincali;" in Hungary and Transylvania, where they are very numerous, they are called "Czigany;" but they call themselves either "Rommany," a Sanscrit word for husband or head of a family, or "Zincali," meaning the black men of Ind. The notion of their being Egyptians is probably derived from the circumstance that many of them came immediately from Egypt into Europe, but it seems proved that they are not originally from that country, their appearance, manners, and language being totally different from those of either the Copts or Fellahs.

It is now generally believed that the gypsies migrated originally from India at the time of the great Mohammedan invasion of Timur Beg; that in their own country they belonged to one of the lowest castes, which resemble them in their appearance, habits, and especially in their fondness for carrion and other unclean food. Pottinger, in his 'Travels,' saw some tribes resembling them in Beloochistan. There is a tribe near the mouths of the Indus called Tchinganes.

The language of the Gypsies seems everywhere to be mixed with the slang of the country they inhabit; but there is no doubt that it contains many Sanscrit words, and it has been found to resemble some of the dialects of India. ('Bombay Transactions,' 1820.) They have no traditions or records concerning their origin; no religion of their own, but they adopt the outward forms of the people among whom they live, whether Christians or Mussulmans. Everywhere they exhibit the same roving habits, a dislike to a fixed settlement and to the arts of husbandry, uncleanness in their food, licentiousness, ignorance and intellectual apathy, a disposition to pilfer, and to impose on the credulity of others. They seldom commit violent robbery or other heinous crimes, being fearful of punishment. Maria Theresa ordered those in her states to be instructed in agriculture, with a view to their permanent settlement; but her endeavours were not very successful. In Hungary and Transylvania, however, many of them have fixed habitations, and follow some regular trade; they wash gold from the sand of the rivers, and they work iron or copper; some are carpenters and turners, others are horse-dealers, and even keep wine-shops or public-houses. They abound in Wallachia, Moldavia, and Bessarabia, and they are found in Russia as far as Tobolsk. Grellman, in his 'Versuch über die Zigeuner,' Göttingen, 1787, conjectured that there were then between 700,000 and 800,000 in Europe, of whom 40,000 were in Spain, chiefly in the southern provinces. In England and Scotland, in both of which they were formerly numerous and troublesome, and many Acts of Parliament were passed in vain for their suppression, they have much diminished of late years, in consequence chiefly of the inclosure of land and the more effective execution of the laws against vagrants. J Hoyland published the best information that could then be procured concerning this strange race, in his 'Historical Survey of the Customs, Habits, and present State of the Gypsies; designed to develope the Origin of this Singular People, and to promote the Amelioration of their Condition,' 8vo, York, 1816. He has largely made use of the work of Grellman; but for a correct account of the peculiar manners, language, and probable descent of the race, the best authority is Mr. G. Borrow, particularly his 'Zincali; or an Account of the Gypsies of Spain.'

GYPSUM. The hydrous sulphate of lime furnishes materials which are extensively used in building operations, either for the purpose of obtaining *plaster of Paris* from the amorphous varieties; or for ornamental sculpture, when the gypsum assumes a sub-crystalline anhydrous character, known by the name of alabaster. The amorphous gypsum is raised in enormous quantities in parts of Lincolnshire and in Derbyshire, in the neighbourhood of Paris, in Provence, Tuscany, north of Spain, lower Austria, Nova Scotia, &c. The anhydrous varieties are principally obtained from the département of the Isere in France, Volterra in Tuscany, and the Guadalajara in Spain. The gypsum of the tertiary deposits of France, it may be added, contains a notable proportion of carbonate of lime, and even of soluble silica; and it is no doubt on this account that it is able to be employed in external masonry, which is not the case with the English plaster. Another peculiarity of the real plaster of Paris is that it swells with inconceivable force in setting, and therefore requires to be used with great caution.

Some artificial plasters are made, under the names of Keene's, Martin's, and Parian cements, by slacking the dehydrised sulphate of lime with solutions of borax, alum, or other salts, and then exposing it to a second calcination.

GYPSUM. [CALCIUM, *Lime, Sulphate of.*]

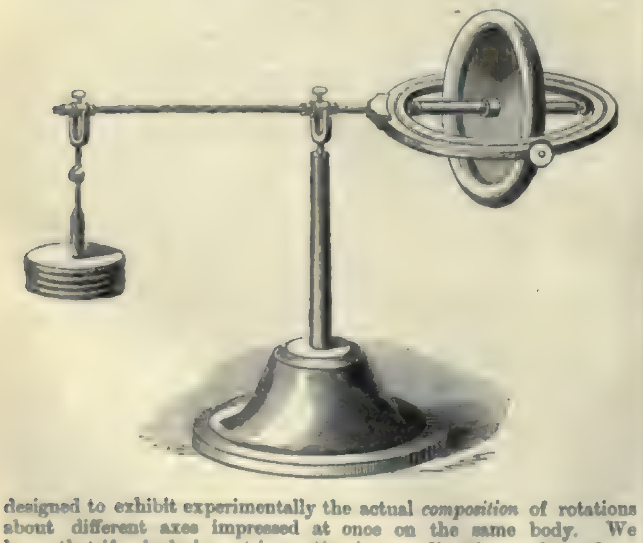
GYRATION, CENTRE OF. When a system of heavy bodies, or any system possessing weight, has a fixed axis of revolution, the centre of gyration is a point at any such distance from the axis, that the *moment of inertia* would not be altered if the whole mass were collected at that point. The moment of inertia being found by multiplying every mass by the square of its distance from the axis, the distance of the centre of gyration is found by dividing this moment of inertia by the whole mass, and extracting the square root of the quotient. As this term is now very little used, we refer to INERTIA for further information.

GYROPHORIC ACID. [LICHENS, COLOURING MATTERS OF.]

GYROSCOPE (from the Greek *γῦρος*, a circle or rotation, and *σκοπέω*, to perceive), an instrument recently suggested by M. Foucault, and improved by various modifications, and which has acquired notoriety from its supposed efficiency in rendering *visible*, by its direct dynamic effects, the diurnal *rotation* of the earth on its axis. It seems to have been originally invented in the form of *fig.* 1, by M. Fessel of Cologne, and was described in Poggendorff's 'Annalen' for September, 1853. It has since been modified and improved by Professor Plücker, and Mr. Wheatstone, and although originally invented apparently without any knowledge of Bohnenberger's apparatus, is merely a modification of it, as described in Gilbert's 'Annalen' (lx. p. 60). The essential parts of Bohnenberger's apparatus were a sphere capable of rotating about an axis whose extremities rest in opposite points of a hoop which can turn on pivots *horizontally*, within another hoop turning on pivots about a *vertical* axis.

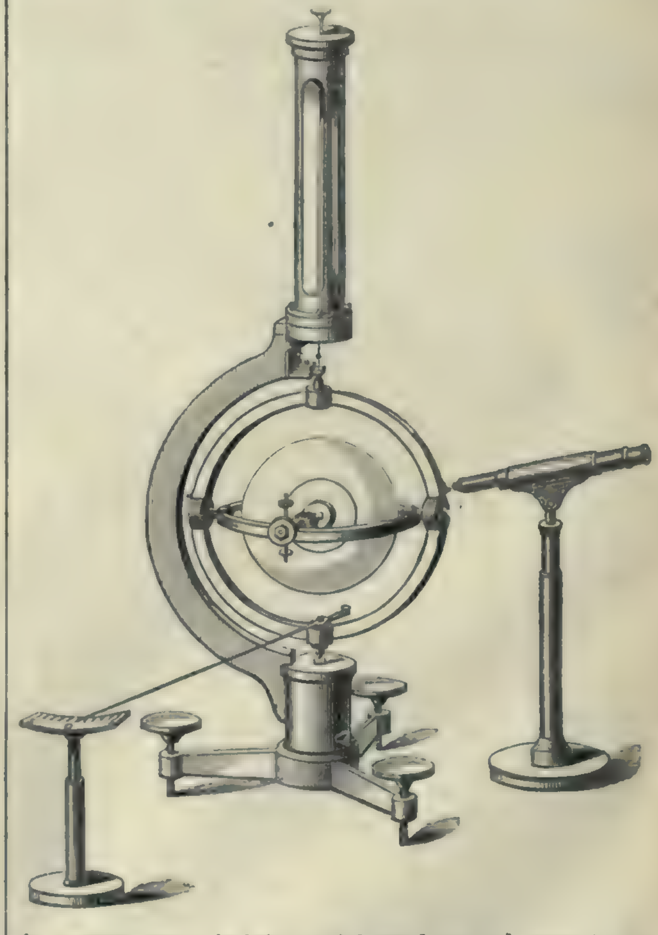
The principle on which the action of the instrument depends was discovered by Frisi about 1750, and enunciated as the principle of the "composition of Rotatory Motions;" and the instrument itself is designed to exhibit experimentally the actual *composition* of rotations about different axes impressed at once on the same body. We know that if a body be set in motion in one direction, and any force tend to make it move in another direction, it will move in neither, but in an intermediate direction. So also we have the strictly analogous case of *rotatory* motion, namely, when a body is rotating about an axis, and any force tends to make it rotate about another axis, it will not rotate about either, but about a new axis intermediate to the other two. Thus, to take a very simple, but paradoxical case (given by Professor Baden Powell, in a paper read at the Royal Institution, in March, 1854):—a wheel at one end of an axis, and a weight at the other, are suspended in equilibrio; which is, of course, unaltered, whether the wheel be at rest or in rotation; the weight is then slid so that the balance is destroyed; *now* if the wheel be set in rapid rotation, the equilibrium is restored.

Fig. 1.



The *apparent* displacement of the plane of vibration of the pendulum was first noticed by the Academicians *del Cimento*. This fact was brought to light in 1851, by Signor Antinori, director of the Museum at Florence, who found an autograph manuscript on the subject by Vincento Viviani; this note however was not published until after Foucault's discoveries, who was the first to connect this fact with the rotatory motion of the earth. M. Foucault communicated his discovery to the Academy of Sciences at Paris, on the 3rd of February, 1851. His experiment with the pendulum will be fully described under the article PENDULUM, while we shall confine ourselves here to his later invention, the gyroscope, for showing the same rotatory motion of the earth. We shall, however, first mention M. Lionville's connection between this rotatory motion and the displacement of the plane of rotation of the pendulum or disc of the gyroscope. The rotation of the earth *on its axis* has been proved by Foucault (1) by his celebrated pendulum experiment, (2) by his gyroscope. (1) Suppose a pendulum suspended over either pole of the earth, and set in oscillation. It is evident that a spectator, carried round by the rotation of the earth, would pass, first under one end of the arc of the vibrating pendulum, and then under the other, so that its plane of oscillation would appear to him to make a revolution *from east to west* in the same time as the earth revolved *from west to east.* (2) Let the pendulum be similarly suspended over the *equator*. It is evident that in this case no change of the plane of oscillation can take place, because the spectator cannot, by being carried round, approach nearer to one end of the arc of vibration than the other. (3) If the pendulum is suspended at any *intermediate latitude*. In this case, the rotation of the earth round the polar axis may be considered as the resultant of two rotations, one round an axis passing through the place of observation, and another round a perpendicular axis. But the rotation round

Fig. 2.



the latter axis, or polar axis of the place, cannot affect the apparent motions of a pendulum suspended at the equator of that axis, which is the great circle through the place of observation. The pendulum will therefore be affected only by a motion round the axis through the place, which is the case *first* investigated. And the *amount* of this motion will evidently vary as the sine of the latitude. Hence the time of *apparent* revolution of the plane of oscillation = a sidereal day × sine of latitude.

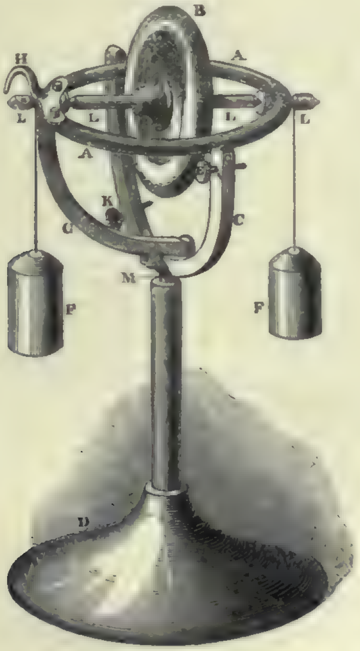
The gyroscope is an application of the well-known principle of the dynamics of a rigid body, that if a mass be set in rotation freely in space, it will, unless it be disturbed, preserve in all cases its original plane of rotation, and to effect this, will even overcome slight impediments. It will be easily seen from fig. 2, and from the description given above of the instrument itself, how the rotation of the earth is hence deduced. It was in September, 1852, that M. Foucault presented to the Academy of Sciences an account of the gyroscope. In this apparatus also there is a fixed plane below which the earth turns, and as it carries with it the spectator, causes it to appear to him as if the plane of the disc actually revolved.

The disc has the mass composing it disposed as much as possible around its edge, in order that, when put in rotation, it may revolve for a longer time than it otherwise would.

Since all the particles of this rotating disc have a tendency by virtue of *centrifugal* force to fly off at a tangent to the circumference of the disc, *in the plane* in which it is vibrating; hence, any attempt to change the direction of this plane in space will be opposed by part of the force with which, were they not restrained by the law of cohesion, each particle of the disc would fly off.

Mr. Wheatstone has described in a paper, read before the Royal Society in April, 1854, a form of the gyroscope, *fig.* 1, which we will briefly describe, as the experiments performed with it will be very easily transferred to the more perfect form, *fig.* 3. It is thus constructed: a beam is capable of moving freely round a horizontal axis, which is itself moveable round a vertical axis, so that the beam may move in any direction round a fixed point; at one end of the beam is fixed a horizontal ring which carries a heavy disc, the axis of rotation of which is in a line with the beam; at the other end is a shifting weight by means of which the equilibrium of the beam may be established or disturbed at pleasure.

Fig. 3.



If the beam be brought into equilibrium, and the disc be rapidly rotated, as by means of a string quickly unrolled from its axis, the beam will have no tendency to displace itself in any direction. But if we now disturb in any way the equilibrium, moving the weight towards the centre of the beam, and thus causing the *disc* to preponderate, then, if the disc rotates from right to left, the beam will move round the vertical axis also from right to left, and *vice versâ*. If we cause the *equipoise* to preponderate, contrary effects will take place.

The velocity of rotation of the beam round the vertical axis increases in proportion to the disturbance of the equilibrium. Notwithstanding too the increased or diminished action of gravity on the disc, its axis of rotation always preserves the same inclination to the vertical axis at which it was originally placed. When the equilibrium is disturbed while the disc is at rest, the beam being placed in any other position than the vertical, gravity acts so as to turn it round a *horizontal* axis; but when the disc is in motion, the usual effect of gravity disappears, and there is substituted for it a continued rotation round a *vertical* axis, that is, round an axis perpendicular to the plane containing the axes of the two impressed rotations.

A similar composition of forces takes place when the disc is caused to rotate while the equilibrium of the beam is preserved, by impressing on the beam a rotation round a vertical axis. When the disc rotates from right to left, the slightest pressure tending to produce rotation round the vertical axis in the same direction, causes the end of the beam carrying the disc to ascend, and a pressure in the opposite direction causes it to descend, that is, the beam is constrained to move round a horizontal axis perpendicular to the vertical plane containing the two axes of impressed rotation—a case exactly analogous to the preceding. The beam ascends and descends in like manner, after rotation has spontaneously taken place round the vertical axis in consequence of the equilibrium being disturbed, whenever this rotation is in any way accelerated or retarded. As the centre of gravity of the beam is below its point of suspension, even when equipoised, it is in perfect equilibrium only when it is horizontal, consequently, if it be elevated above or depressed below this position, it will endeavour to resume it, tending to produce in the two cases rotation in opposite directions round a horizontal axis; the rotation of the disc combined with this tendency, gives rise, as in the other cases, to continued rotation round a vertical axis; the direction being determined in a similar manner.

In all these experiments the axis of the rotating disc has been supposed to be fixed in the prolongation of the beam; but now let us suppose this axis placed at any inclination and any azimuth with respect to it, it is evident that the inclination of this axis should produce no difference in the *character*, but merely in the *intensity*, of the effects, since in any inclined position of the disc its rotation is resolvable into others, one perpendicular to the beam, and the other, which produces no effect, in a plane containing it. When the axis of the rotating disc is vertical and at right angles to the beam, no rotation on the vertical axis ought to take place in any case; but it is found that, although the beam be horizontal and in equilibrium, there is a motion round the vertical axis in opposite directions, according as one or other end of the axis of the disc is uppermost. This motion, however, is evidently due merely to the friction of the pivots dragging the beam to a corresponding motion; because whether it be accelerated or retarded no change is produced in the horizontality of the beam.

To take a few more experimental illustrations: let the system of rings carrying the disc be removed from the rest of the apparatus, and let the inner ring be allowed to move freely within the outer. Having set the disc in rotation, hold the outer ring at the end of the diameter which is in the plane in which the axis of motion of the disc is free to move; then giving to the outer ring a tendency to rotation round that diameter, in whatever position the axis is, it will fly to place itself in the fixed axis thus determined, and rotation will take place round it in the same direction; while considerable resistance is felt so long as the moveable axis is changing its position; but when once it coincides with the fixed axis, the rotation of the external ring is easily effected. So, also, a slight *alternate* motion of the outer ring, tending to give it rotation in opposite directions, will cause a continued rotation of the moveable axis; and similarly, when we try to rotate the outer ring round an axis perpendicular to its plane. In all cases, when the axis of the rotating disc is free to move in a plane, and the outer ring is constrained to rotate round a line in this plane, the moveable axis will place itself so as to coincide with that line, and so that the disc shall rotate in the same direction as the ring; if the fixed axis be in a different plane, the moveable axis will assume permanently that position in its plane which approaches nearest to the former. The moveable axis is thus *apparently* attracted towards the fixed axis, if the rotations are in the same direction, and repelled from it if they are in opposite directions.

In all these experiments the free and constrained axes of rotation are supposed to intersect, but in Fessel's apparatus they are distant from each other. In this case, the rule must be thus modified, that the free axis of rotation tends to place itself *parallel* to the constrained axis, or as nearly so as possible. By this principle all the results are easily explained. Thus, when the equilibrium of the beam is destroyed gravity tends to make it rotate round a *horizontal* axis; the axis of the disc tries to place itself *parallel* with that axis, but being unchangeably at right angles to it, the tendency to place itself there causes rotation round the *vertical* axis.

Again, fix the outer ring horizontally, and loosen the inner ring, keeping them, however, both in the same plane; then, on moving the beam round the vertical axis, the axis of the disc will fly to place itself parallel thereto. The rings being placed in the vertical plane, the same result will follow, if the beam be moved in a vertical plane, that is, round a horizontal axis of rotation.

Before describing a few more experiments with the gyroscope, we will again revert to its theoretic action, in order to explain more clearly the phenomena. We quote from a pamphlet, by Mr. Ladd, of Chancery-lane, accompanying his instrument:

"Every particle of a disc revolving on an axis has a tendency to fly therefrom, on account of centrifugal force; but diametrically opposite are the similar particles exerting the same influence on the axis. This force, influencing the axis all around, causes the rotating body to tend to preserve its plane of rotation, and with the size of the rotating body it requires a considerable increasing force to displace its axis. This fact being well understood, presents the key to the explanation of all the experiments that the instrument is capable of exhibiting.

"When the disc B is rapidly rotating, and the stand D is turned, the axis I I of the disc B will constantly point in the same direction. The friction of the vertical axis must be considered as nothing; therefore, the tendency of the disc to keep the plane of rotation is not impeded, and no effect is produced upon the same; and similar is the case when the gyroscope is taken by the stand and moved in any direction. Even an inclination of the stand D in the plane of the axis will produce no effect: that is, if the axis stand horizontally, it will continue to do so; but attempting to turn the semicircle C to the right or to the left hand, the axis of the disc will take up such a position as to coincide with the new axis which the experimenter is endeavouring to confer. In such instance two forces are simultaneously summoned into activity—the force of the hand, and the tendency of the disc to keep the plane of rotation; and the former being infinitely greater than the latter, the disc can only move in the prescribed direction. If the semicircle C and the gymbal A be connected by means of a milled headed screw K, no resistance will be felt either way. The same will be the case in one direction if the quadrant G be attached to the semicircle C; but then some other phenomena occur, because the two axes are at right angles with each other. The impossibility of the one force exerting its influence, leaves the other force free to act, as though the other were not in existence; but the force is only apparently lost, for a slight push against the semicircle will cause the instrument, as it were, to revolve round the stand on the table: that is to say, the instrument lifts a little from the table, and plays around the surface of the stand. In this manner the force that is stopped by the quadrant shows again at the bottom of the stand. If a weight F be suspended in the continuation of the axis on the screws L L, it will be unable to draw the same down, but will impart a slow horizontal motion to the spindle M. This is a beautiful and important experiment:—if the rotation of the disc be stopped, the weight will draw it down; if the horizontal motion of the semicircle be stopped, the weight will draw the disc down, however rapid may be the rotation; that is, remove the possibility that the compound effect can take place, and the one that is left at liberty will act as though the other had no existence. This remarkable fact bears analogy to some of the most important truths of the 'Mécanique Céleste.' If the rotation of the earth were stopped it would fall upon the sun, and if the possibility of the orbital revolution of the earth round the sun were stopped, it would fall upon the sun, notwithstanding its axial rotation. When the ring A with the rotating disc B is detached from the semicircle C, by lifting the screw K, and suspended by a string on the screw-head L, the disc will stand horizontally, and whilst so suspended it will revolve slowly round the suspending string as a centre of motion; the tendency of the rotating body to keep the position of its axis is so great as to resist the action of gravity on the mass, even if an extra weight be suspended on the opposite screw-head L. Another modification of the experiment is to let the arrangement rest on a hook H in the continuation of the axis in a hollow attached to the stand. If the weight be changed to the opposite side, the semicircle will turn in the opposite direction. The rotating disc freely moved in all directions by the hand, will furnish a very good proof of the resisting force which is opposed to any endeavour to change the plane of rotation; and if placed with the screw-head L on the table, it will keep itself upright like a spinning-top; and if the friction between the screw-head and the table be greater than between it and the point on which the axis turns, the ring will remain stationary. Close to the disc on the axis is a milled wheel, which may serve as a means of calculating the number of revolutions in a second. If a card be held against it, a musical tone is produced, which will rise higher with the rapidity of the rotation; if the note be taken, and the number of the teeth in the milled wheel be known, the number of the rotations can be calculated by an acoustical table."

The gyroscope then, illustrates the following principles:—

1. That inertia is a property of matter in motion, as well as of matter at rest.

2. That the power possessed by the shots projected from rifled guns of resisting the influence of gravity, is due to the *gyratory* motion given to the ball.

3. That *orbital* and *axial* motions are intimately connected, and that the speed of one may regulate that of the other.

4. That the condition of *unstable* equilibrium in which bodies remain *as if stable* (for example, a common top) is due to their rotation.

Hence the gyroscope exhibits in a marked degree the three laws of inertia.

1. That a body at rest cannot move itself.
2. That a body in motion cannot stop itself.
3. That a body in motion cannot change the plane in which it is *rotating*, any more than it can diverge from a straight line if it has only a motion of *translation*.

The mathematical explanation of the movements of the gyroscope is founded on the two following principles, given by the Rev. W. Cooke, in the 'Proceedings of the Royal Society,' for March, 1857:—

I. When a particle is made to move $\left\{\begin{matrix}\text{towards}\\ \text{from}\end{matrix}\right\}$ a plane by any applied force, but in consequence of its connection with some rigid body on the same side of the plane, loses some of its momentum in a direction perpendicular to the plane; all the momentum so lost is imparted to the rigid body, which is consequently impelled $\left\{\begin{matrix}\text{towards}\\ \text{from}\end{matrix}\right\}$ the plane.

II. When a particle is made to move $\left\{\begin{matrix}\text{towards}\\ \text{from}\end{matrix}\right\}$ a plane by any applied force, but in consequence of its connexion with some rigid body on the same side of the plane, receives an extra momentum in a direction perpendicular to the plane; all the momentum so gained is taken from the rigid body, which is consequently impelled $\left\{\begin{matrix}\text{from}\\ \text{towards}\end{matrix}\right\}$ the plane.

Let the mass of the disc of the instrument be supposed compressed into its circumference; let its radius $= r$, and let it revolve round its axis with a given uniform angular velocity $= w$.

Masses will be represented by weights; hence any accelerating force f, is due to a pressure P, acting on a mass W, so that $f = \frac{P g}{W}$, g being the accelerating force of gravity.

The centre of gravity of the disc, axle, and ring which carries the pivots of the axle, is fixed, and the whole is moveable about that centre in any manner, subject to the condition that the line of the pivots of the ring is always horizontal. Let the line of the axis be denoted by II (see *fig.* 3), and be $= a$.

Let a given force F be applied at L, in the form of a weight suspended there perpendicular to the plane A A, so that the disc may describe an angle ϕ round the lines of the pivots F in the time t, whereby any two particles m and m' in the disc describe the two arcs y and y' simultaneously. Suppose the circumference of the circle A A divided into four quadrants, and let m and m' be in the first quadrant, so that $y' > y$; then, if the disc is supposed to revolve, a particle m is carried from y to y', so as to acquire an increase of velocity from the plane A A, independently of the force F, and consequently (by the first of the above principles), all the momentum so required by the particle is lost to the disc, ring, &c.; which are thus impelled as by a force in the direction opposite to that along y or y', so as to oppose the rotation imparted by F, but to impart another round the centre of the disc, in the direction A L E in the plane of the ring, that is, in a plane perpendicular to that in which F acts. A force having the same tendency is found, by means of one or other of the above principles, in the other quadrants. Hence it may, without much difficulty, be deduced by D'Alembert's principle that

$$\phi = \frac{4 F a g}{W r^2 w^2} \sin^2 \left(\frac{w t}{2}\right)$$

This value being periodical, and ranging between the limits 0 and $\frac{4 F a g}{W r^2 w^2}$, shows that the disc makes an oscillation of less extent and duration, as the spinning of the disc is more rapid, that is, as w^2 is made greater compared with $\frac{F}{W}$; and if F be a *small* weight, as is generally used, the extent of the oscillation becomes insensible. The theoretical *maximum* of ϕ for a common instrument has been found $= 18'$.

That these oscillations do exist will be evident, if we consider that the gyroscope, with the weight attached, becomes an ordinary pendulum; and the effect of the spinning is to disturb its oscillations, and lessen their extent indefinitely, when the angular velocity of the disc is sufficiently great.

H

H is an aspirate of the guttural series, and is a faint pronunciation of the sound which in the German alphabet is denoted by *ch*. In the earliest alphabets, as the Greek and Hebrew, the symbol whence the modern character is derived [Alphabet] denoted the syllable *che* or *he*. Hence the Hebrew name was *cheth* or *heth*; and the Greek probably at first *heta*, as it was afterwards *eta*. As the guttural sound disappeared in the latter language, the letter finally denoted the simple vowel ē. On the other hand, in the Latin alphabet it was retained as the symbol of the aspirate. The English name *aitch* was probably at first *ech*, with the vowel prefixed, as in *ef*, *el*, &c. The guttural sound of *ch* is often confounded with the sibilant *ch*, as heard in *church*.

The letter *h* is liable to the following changes in different dialects or kindred languages:—

1. H is interchangeable with *c*. This is well seen in a comparison of the Latin and German languages [C, 3]. To the examples there given may be added the Latin *decem* compared with the German *zehen*, and *ducere* compared with *ziehen* (*zug*).

2. H is interchangeable with *ch*. Thus the Greek forms χειμ-ων, χειμερινος, χορτος, χαμαι, are severally connected with the Latin *hiems*, *hibernus*, *hortus*, *humi*.

3. H with *chth*. This is similar to the interchange of *p* with *pt*, as seen in the Greek nouns πολις and πτολις, πολεμος, and πτολεμος. Of the interchange between the aspirates there are examples in the Greek χθες compared with the Latin root *hes-*, seen in *heri* and *hesternus*, and perhaps the Greek χθον (nom. χθων) compared with the Latin *humo-* (nom. *humus*).

4. H is interchangeable with *g*. Examples: the German *zehe* compared with the Latin *digito-*: the German *fliehen*, *sehen*, compared with the English substantives *flight*, *sight*; and perhaps the Latin *vehemens*, the first element of which is identical with the German prefix *weg*, a derivation which will make *vehemens* equivalent to *amens* or *demens*.

5. H with *s*. Compare the Latin *sub*, *sex*, *septem*, *sus*, *salio*, with the Greek ὑπο, ἑξ, ἑπτα, ὑς, ἁλλομαι, &c. Thus the ancient Spanish town Hermandica, mentioned by Livy in his 21st book, is proved by the Greek form Helmantice to be identical with Salmantica, the ancient name of Salamanca.

6. H with *f*. Hence the Latin words *hostis*, *hostia*, says Festus, were sometimes written *fostis*, *fostia*. So, too, the French word *hors*, well known in the phrase *hors de combat*, is derived from the Latin *foris*. The Spanish language abounds in examples of this change, as in the names *Herdinando* and *Ferdinando*; so also *hermoso*, from the Latin *formoso-*; the Portuguese retains the form *formoso-*.

7. H with *w*. Many Greek words which had originally the digamma (another name for the letter *w*) at the beginning, took a mere aspirate afterwards. So in our own language the word *who* has nearly exchanged the *w* for what is sounded as an *h*; and the relative adverb *how* is no doubt derived from the relative itself. It is in this way that the Latin *homo* (*homon-*) is *uomo* in Italian and *whom* in Walachian.

8. When any consonant or consonants in the middle of words had nearly lost all sound, the letter *h* appears to have been employed as a fit representative of the vanishing sound. Hence in German *stehen* and *gehen*, for what must originally have been *standen* and *gangen*; but the *h* of the Latin *mih-i* is part of the stem, as shown by the German forms *ich* and *mich* of the same pronoun.

9. The letter *h* is often dropped altogether in pronunciation, and hence in writing also. This was perhaps the reason why the Greeks gave up the letter *h* for the little mark called the *spiritus asper*. In Latin many words are written indifferently, with or without an *h*, as *arena*, *harena*; *arundo*, *harundo*; *onustus*, *honustus*. Thus the last words show that *hon-or* and *hon-us* (*onus*), *honestus* and *honustus*, are all of the same origin, being derived from a root *hon*, denoting a *load* or *charge*, which is either an *honor* or a *burden*, according to the nature of the case. The Italians for the most part, like the inhabitants of ancient Rome, are averse to all aspirates; the people of Tuscany, on the other hand, still maintain their ancient character for the strongest pronunciation of these harsh sounds. Evidence of this is seen in the name *Leghorn*, which no doubt more accurately represents the pronunciation which prevailed on that part of the Italian coast, than *Livorno*.

HABEAS COR'PORA JURATO'RUM, a judicial writ for the purpose of enforcing the attendance of jurors, abolished by the Common Law Procedure Act, 1852. [Jury.]

HA'BEAS CORPUS is a writ at the common law, used for various purposes. When the writ of Habeas Corpus is spoken of without further explanation, it always implies the important writ which will presently be described; but it is also used for certain formal purposes in the courts of common law at Westminster for removing prisoners from one court into another, and for compelling the attendance of prisoners as witnesses, &c. But the great writ of Habeas Corpus is that which in cases of alleged illegal confinement is directed to the person who detains another; and the purport of the writ is a command to such person to produce the body of the prisoner, and to state the cause of his detention, and, further, to submit to and receive whatsoever the judge or court awarding the writ shall direct.

The old writ *de homine replegiando* was issued for the purpose of replevying a man out of custody in the same manner as chattels taken in distress may be replevied [Replevin] upon giving security to the sheriff that the man should be forthcoming to answer any charge against him. And if the prisoner was removed out of the sheriff's jurisdiction, the sheriff might make his return accordingly, and thereupon a process issued (called a *capias in withernam*) to imprison the party withholding the prisoner until he was produced. From the many exceptions, however, with which this writ was guarded, especially in causes where the crown was concerned, it was a very insufficient remedy. The decision of the judges of the King's Bench in the early part of the reign of Charles I., that they could not, upon a Habeas Corpus, bail or deliver a prisoner, though committed without any cause assigned, in cases where he was committed by the special command of the king, or by the lords of the Privy Council, caused the parliamentary inquiry which was followed by the Petition of Right, which recites this judgment, and enacts that no freeman shall be so imprisoned or detained. The court, however, and the judges, still endeavoured to uphold the prerogative of the crown; and, consequently, the statute 16 Car. I. c. 10, was extorted by the parliament, enacting that any person committed by the king himself or his Privy Council, or any members thereof, should have the writ of Habeas Corpus granted to him upon demand or motion made to the court, which should thereupon, within three court days after the return of the writ, examine and determine the legality of the commitment, and do justice in delivering, bailing, or remanding the prisoner. Still, however, new shifts and devices were made use of to prevent the due execution of this act, and eventually the statute 31 Chas. II., c. 2., was passed, which is called the Habeas Corpus Act, and is frequently spoken of as another Magna Charta. By this statute the methods of obtaining this writ are plainly pointed out, and so long as it remains in force no English subject can be long detained in prison, except in those cases where the law justifies a detainer. And lest it should be evaded by demanding unreasonable bail, it is declared by the 1 W. & M., stat. ii., c. 2, that excessive bail shall not be required.

It has been customary in times of alleged danger to suspend the Habeas Corpus Act; but these are in fact the very times when the statute is most necessary. The Habeas Corpus is the protection only of the innocent, not the defence of the guilty. A suspension of the Habeas Corpus Act is effected by an act of parliament authorising the crown, for a limited period, to imprison suspected persons without giving any reason for so doing. But it has been customary to pass acts of indemnity subsequently, for the protection of those who have acted under the suspension. An instance of the one is afforded by the 57 Geo. III. c. 3, and of the other by the 58 Geo. III. c. 6. (Blackst., 'Comm.,' Mr. Kerr's ed., vol. iii.)

The statute 31 Chas. II. has been re-enacted or adopted, if not in terms yet in substance, in most of the American states. The New York statutes formerly provided for relief under the writ *de homine replegiando*, in favour of fugitives from service in any other state; but this provision has been held to be contrary to the constitution and laws of the United States, and void in respect to slaves being fugitives from states where slavery is lawful. (Kent's 'Com.')

HABE'RE FA'CIAS POSSESSIO'NEM, a judicial writ directed to the sheriff, commanding him to put the person who has recovered a chattel or possessory interest in lands into actual possession. It corresponds to the *Habere facias seisinam*; but now that the possession alone is recovered in ejectment, this writ is the one most in use. [Execution.]

HABE'RE FA'CIAS SEISI'NAM, a judicial writ directed to the sheriff, commanding him to put the person who has recovered a freehold interest in lands into actual possession. In the execution of this writ, as well as of the writ of *Habere facias possessionem*, the sheriff may justify breaking open doors if the possession be not quietly delivered. The execution is effected by the delivery of a twig, or a clod, &c., if land; or by the delivery of the key of the door, &c., if a house is the subject matter of which the sheriff is directed to put the recoveror in possession,—all other persons being first removed from the premises. But if it be the presentation to a benefice which is recovered, the execution is by writ *de clerico admittendo*, directed, not to the sheriff, but to the bishop or archbishop, directing him to admit and institute the clerk of the recoveror. [Execution.]

HACKNEY COACH. [Stage Carriage.]

HÆMATE'MESIS (from αἶμα, blood, and ἐμέω, to vomit), a bleeding from or into the stomach. [Hæmorrhage.]

HÆMATO'CELE (from αἶμα, blood, and κήλη, a tumour), an effusion of blood into the scrotum.

HÆMATO′XYLON CAMPECHIA′NUM (Logwood), a tree native of Campeachy, but cultivated also in both the West and East Indies. The finest wood is the produce of the former place. The bark and alburnum being removed, there is within a dark red coarse-fibred duramen, having a violet-like odour, and a taste at first sweetish, afterwards astringent. It dyes the saliva violet-coloured, and produces a similar change on many of the other secretions. Specific gravity, 1·057. Ten pounds of wood yield 16–18 ounces of extract. Its chief constituents are volatile oil, resinous or fatty matter, a principle termed *hæmatoxyline*, which is occasionally found in the wood in the form of crystals, and a brown matter containing tannin.

Logwood acts as a mild astringent in hæmorrhages or increased secretions; and in some forms of diarrhœa it often effects a cure where more powerful astringents fail. (See Abercrombie on 'Diseases of the Stomach, &c.') It may be exhibited in the form of infusion or of extract: the former is preferable. It is accused of causing phlebitis, or inflammation of the veins, in some cases where it had checked the diarrhœa; but this is very rarely met with. Logwood is also used extensively in the arts, especially for dyeing. It gives the peculiar colour to the paper in which sugar-loaves are generally wrapped. It forms the basis of red ink, when Brasil wood is not used.

HÆMATU′RIA (from *αἷμα*, blood, and *οὖρον*, urine), voiding of bloody urine. [Hæmorrhage; Kidneys, Diseases of.]

HÆMO′PTYSIS (from *αἷμα*, blood, and *πτύω*, to spit), a spitting or coughing of blood. [Hæmorrhage; Lungs, Diseases of; Phthisis Pulmonalis.]

HÆMORRHAGE (from *αἷμα*, blood, and *ῥήγνυμι*, to break). The most common cause of hæmorrhage is external violence, by which the vessels of a part are divided, and the blood escapes from their cavities. When an artery of some calibre is wounded, a bright scarlet stream of blood is propelled to a distance proportioned to the size of the vessel, in a current continuous, yet increased in force at intervals corresponding with the pulsations of the heart. This is called a jetting stream. If a vein of some size be divided, a stream of dark crimson blood is projected in a perfectly continuous and equable current, and with less force than from an artery of the same calibre, in consequence of the loss of power which the blood sustains in its passage through the minute capillary vessels. In wounds in which no vessel of more than a line in diameter has been divided, the blood flows in a constant more or less rapid oozing, but is not projected to any distance from the body; and when it issues from both kinds of vessels at once, and in equal quantities, its colour is intermediate between those peculiar to each of them. The same mixture of the two kinds of blood may sometimes, when a number of small vessels of both kinds, and a large one of either kind, are simultaneously divided, make it doubtful, from the colour alone, to which kind it belongs; and the distinction becomes still more difficult if the arterial blood be long detained in the tissues, for then it assumes a venous colour.

When a large artery, as one of the main trunks of the limbs or head, is divided, the blood rushes forth with such impetuosity that life is often destroyed almost instantaneously. The quantity of blood lost however, and the rapidity with which death ensues, will depend in some measure on the freedom of exit which the blood finds after issuing from the wounded vessel, as well as on the mode in which it is wounded. If there be a free external aperture, no obstacle is presented to its flow, and death speedily follows; if, on the contrary, the aperture be small, as in a punctured wound, the blood can escape but slowly, and is liable to coagulate in the passage, so as partially to block it up and render it still more narrow. If again the artery be completely divided, its extremities will retract into the tissues around, and be thus partly covered, so that the hæmorrhage will be retarded. If it be cut longitudinally, the blood will flow much less rapidly than if the wound be transverse, because the aperture will gape much less widely. If, lastly, the wound be not cleanly made, if the edges be rough and torn, as by a gun-shot, no blood at all will flow, at least for some time. None of these circumstances, however, is likely to do more than retard the fatal consequence of a wound of a large artery, unless immediate assistance be given.

When an arterial branch of the second magnitude, as one of the primary divisions of the main trunks in the leg or fore-arm, is wounded, the flow of blood is at first profuse, and a large quantity is soon lost; but after a time the patient faints from extreme exhaustion, and then the heart ceasing to act the blood no longer flows, but begins to coagulate both within and around the vessel, whose extremities contract, and further loss may thus be prevented. More frequently, however, as soon as the patient recovers from his exhaustion, and the heart regains some of its power, the slight obstacles formed during the fainting are forced away, and the hæmorrhage recommences and continues till the patient is again exhausted. Thus by a succession of hæmorrhages and of temporary staunchings, he may at last be destroyed by extreme debility. From arteries of smaller size, as those about the fingers, &c., the blood flows at first in a rapid little stream, but after a few minutes, if they are exposed to the cold air, they retract; their orifices contract and close, and the bleeding altogether ceases, without much danger of returning.

Hæmorrhage from wounded veins is of less importance. It is much more slow, for the blood is prevented by the valves from flowing from that part of the vein which is between the heart and the orifice, and in the part which is beyond the orifice it has only the force of that in the smaller arteries. Hence it is seldom immediately fatal, and when the patient becomes faint the edges of the vessel fall together, instead of remaining open as those of arteries. Thus a coagulum forms within and around them, and, except from the largest trunks, prevents any further flow. Other cases in which bleeding takes place from large vessels are those in which they are burst by sudden efforts, as sometimes happens in the aorta, especially when it or the heart is diseased; those in which the walls of an aneurism or otherwise diseased artery or vein burst or ulcerate; those in which ulceration, whether in internal or external organs, spreads from surrounding parts, and at last (though they always resist for a long time) invades the walls of arteries and veins. The bleeding so common from ulcerated surfaces, and from various vascular morbid growths, probably depends on rupture of the very delicate vessels which they contain; and the same delicacy of the walls of its vessels, with their great liability to disease in advanced life, may be assigned for many cases of hæmorrhage in the more vascular parts of the brain producing apoplexy.

But bleeding to a great extent may take place without visible rupture of any vessel. This form of hæmorrhage, which may take place in various parts of the body, is that popularly supposed to arise from the "bursting of a blood-vessel;" but in the large majority of cases where blood is poured forth in the interior of the body, the most careful examination can discover no aperture through which it had flowed. It is therefore called hæmorrhage by exhalation, from the idea that the vessels which in health are traversed only by the fluids of the exhalations or secretions, now permit the passage of the blood. The only instances in which the blood has been seen flowing in these cases are those extremely rare ones of hæmorrhage from the skin of the face, hands, feet, &c. In these the surface is covered by a dew of blood; if this be wiped away no unnatural appearance is perceptible, but the blood soon exudes again. From this the process would appear to be very similar to that of menstruation. When internal organs from which hæmorrhage has taken place are examined after death, they are sometimes found loaded with blood, but at others quite pale, their vessels having been completely emptied; when pressed, small clots of blood like grains of sand sometimes ooze out on the surface, as if proceeding from the orifices of secreting ducts. From these and other circumstances it is probable that the blood does pass through the vessels which naturally are permeated by the secretions, though the minute details of neither process are yet wholly explicable. It cannot however be certainly affirmed that the minute blood-vessels are not ruptured, for neither the apertures nor the cicatrices in them could be in any way visible.

The circumstances under which these hæmorrhages take place are various. In some cases they arise from distension of the vessels in consequence of some local excitement, either with or without increased activity of the circulation generally; and in these the flow of blood is preceded by a sensation of fullness and throbbing in the part, which, if visible, appears red and swollen. Such are those which take place in bronchitis, producing some rare cases of hæmoptysis; in dysentery and acute inflammation of the intestines; from the membrane of the nose, producing the epistaxis so common in young persons in robust health; in the brain, producing some forms of apoplexy, especially those connected with hypertrophy of the heart; and occasionally in the acute inflammations of nearly all the tissues. In other cases the main cause of the hæmorrhage is the existence of some obstacle to the free passage of the blood through the vessels. Such are those very frequent cases in which hæmoptysis, or spitting of blood, takes place in consumption, where the blood is obstructed in its passage through the pulmonary arteries by the masses of tuberculous matter deposited around them; those of hæmatemesis, or vomiting of blood, which arise from obstruction of the splenic or portal vein, by coagula, or by disease of the liver or other adjacent organs, and the consequent congestion of the vessels of the stomach; many of those which occur from the stomach, uterus, and other organs, in the early stages of various structural diseases; those which depend on disease of the heart, producing obstruction in the large vessels, and which may take place in the brain, lungs, and various other organs; and those arising from obstacles in the veins, as in hanging, or even from the influence of gravitation.

But a simply mechanical distension of the vessels, whether from an increased afflux of blood into them, or a retarded removal of it from them, cannot explain all the phenomena of these spontaneous hæmorrhages. In many cases a peculiar condition of the vessels, or of the blood itself, must be assumed, and is indeed nearly proved. To these must be referred many cases of what is called idiopathic hæmorrhage, as in some instances of hæmatemesis, hæmaturia, &c. In some persons, indeed, there appears to be a peculiar disposition to bleeding, a hæmorrhage diathesis. Mr. Abernethy ('Surgical Lectures') used to speak of a bleeding family, in all of whom it was extremely difficult to staunch the blood from even the slightest wound; and among other similar cases are not a few in which fatal hæmorrhage has followed the extraction of a tooth, or, in children, the application of leeches. Every surgeon, also, must have observed that in the same operations in different persons the number of vessels requiring to be tied varies greatly; in some amputations, for example, it is not necessary to secure more than the main artery, while in others eight or more must be tied, and this not admitting of any explanation from local differences

Many other circumstances might be adduced to show that there are conditions of the smaller vessels in which they may not only more easily permit hæmorrhages, but are less capable of effecting those changes which are necessary for arresting them, and on these conditions the majority of the hæmorrhages termed passive must be supposed to depend. Such are especially those from the nose, rectum, and other organs, which occur in persons of weak lax habit, and which may be distinguished from the first class we have noticed rather by the general appearance of the patient than by any local circumstances.

Lastly, there are cases in which the hæmorrhages that take place, often coincidently from several organs, may be presumed to depend on alterations of the blood itself. Such are those that occur in scurvy, in which the blood, when drawn from a vein, does not separate, as in health, into a firm coagulum and a clear serum, but settles into a loose, livid, or dark jelly-like mass, and rapidly putrefies. Such, too, are probably the petechial and other effusions of blood in fever.

Hæmorrhages by exhalation may take place habitually or constitutionally, without injuring the health; most commonly the blood flows from the nose or rectum, more rarely from the lungs or stomach, or even from the skin. They are sometimes periodical; and when occurring in men, have seemed to favour the idea of a periodic action of the system in the male sex as in the female, and the more so as the menstrual evacuation, when suppressed in the latter, is not unfrequently compensated for by hæmorrhage from some other organ. Most of the cases of spontaneous bleeding from the skin are of this class; and in other instances the blood has flowed at regular periods from the gums, the breasts, umbilicus, axillæ, or kidneys, but most frequently from the stomach or lungs. Similar vicarious hæmorrhages occur in men when an habitual discharge from any organ has been suppressed, or when an old ulcer has been suddenly healed.

Of the means of arresting Hæmorrhages.—When an artery is wounded, unless death rapidly follow, a natural process takes place by which further bleeding may be prevented. If completely divided, both extremities retract into the sheath of cellular tissue in which they lie, so that a considerable interval is produced between them, bounded by loose and irregular walls, into which the blood as it flows infiltrates, and, coagulating, tends to fill it up and obstruct the vessel. The open mouths of the artery also contract, and gradually, but at last completely close, either at or just above their extremities. As the stream of blood is thus checked by the narrowing and closing of its canal, at the same time that, by the faintness induced by the previous loss, the action of the heart is weakened and the whole circulation retarded, it begins to coagulate within the vessel itself, till its tube is nearly filled by a clot adhering loosely to its walls. Further changes then ensue; the divided vessel and the parts around become inflamed; coagulating lymph is effused from the edges of the wound into the artery itself and over its extremities, forming a firmer plug than the blood alone had. In process of time this lymph becomes organised, vessels enter it from the parts around, and it becomes firmly and permanently united to them and the vessel, till at length its tube is rendered impervious from the point of division up to the first branch given off from it, and is at last converted into a solid cord, closely connected with the substance of the cicatrix around it. If the artery be only partially divided, the same effects follow; though, if the cut be extensive transversely, with less certainty, because retraction cannot take place, and the internal coagulum, if formed, is washed away by the stream which still partly passes along the vessel. The natural cessation of hæmorrhages from veins is effected in the same manner, but far more easily; for the valves prevent any bleeding from the part nearest to the heart, and both orifices, instead of gaping open, fall together, and soon become adherent.

But in the human subject it is only in the very small arteries that the hæmorrhage can be confidently expected to terminate thus naturally, and hence various artificial means of checking bleeding from the larger ones have been invented. The simplest of these is pressure: if the finger be placed with moderate firmness over the mouth of a small bleeding vessel for a minute or two, on removing it the orifice will be found closed, and no more blood will flow. Pressure is also especially useful when a number of small arteries are bleeding together, with a constant oozing rather than a rapid flow of blood: in such cases, when the edges of the wound are brought together, a compress should be laid on, and bandaged firmly and steadily over them. The same means, or a tourniquet applied a short distance above the wound, so as to compress the trunk of the artery, may be useful by lessening the force and volume of the current, and thus permitting the natural processes to take place undisturbed. But if these means be insufficient, the artery must be tied; if it be completely divided, ligatures must be placed on both extremities; and if only partially cut, then on both sides of the opening—for, from the numerous communications of the arteries, when the main current is checked, another in a retrograde direction is always established into the part beyond the ligature. The operation of the ligature is not merely to prevent mechanically the flow of blood from the opened vessel. When a fine cord is drawn tightly round an artery, something is felt to give way under it, and, on removing it and opening the artery, its inner and middle membranous coats are found cleanly cut through as with a knife, while the outer coat remains. When the ligature is left on, it embraces this outer coat loosely, and thus rendering the canal impervious, completely prevents further bleeding. The blood thus becoming stagnant, coagulates in the lower part of the vessel and adheres to its walls; these at the same time inflame, coagulating lymph is effused from their cut edges, and becoming organised, at last, as in the natural process, completely fills up the canal of the vessel, while the part constricted by the ligature ulcerates and gives way, permitting the cord to be safely drawn away at the end of from six to sixteen days.

Previous to the general use of the ligature, introduced by Ambrose Paré in the 16th century, numberless means for checking hæmorrhages, then so frequently fatal, were resorted to by surgeons, under the names of styptics, astringents, &c. They were in the habit of applying hot irons to the stumps of amputated limbs to stop the bleeding, which it is probable the eschar thus formed would generally effect. At present however the use of the actual cautery is nearly abolished in this country; it can only be justifiable in the few cases where, from peculiarity of situation, the vessel can neither be tied nor compressed, and for such cases it is certainly the most effectual styptic known. Cold air or ice is nearly as useful, and far oftener applicable: it is quite sufficient in all common cases where only small vessels are divided. In the very few cases where any astringents are required, as in some of external bleeding from diseased surfaces or from tumours, the best are solutions of sulphate of copper and of alum. Another class of remedies that may be usefully employed are those which act mechanically—as sponge, agaric, lint, and other light very porous bodies, which placed over a small bleeding orifice will soon completely obstruct it by favouring the coagulation of the blood.

Such are the principal modes of treatment applicable in cases of external or surgical hæmorrhage in which vessels are divided by external injury, and are within reach of the eye or fingers. In internal hæmorrhages however it is obvious that mechanical means can rarely be employed. From the varied nature of the cases from which they arise it is evident that different means may be required in the several kinds of cases. In those so closely related to inflammation, in which there is accumulation of blood from local or general excitement, the hæmorrhage is itself a naturally curative means of its cause, and need not be checked unless it implicates some important organ, as the brain, and then the most advisable means of arresting it is to bleed from the arm. So, too, in cases of habitual or vicarious hæmorrhages, if not dangerous or very inconvenient from locality, it will seldom be advisable to check them, for they are generally outlets by which a plethoric condition that would else be highly injurious is cured; at any rate they should be arrested gradually and cautiously. Where external means are applicable none are so useful as cold, or, as a last resource, pressure; as by plugs put in the nostrils, &c. Where a mechanical obstacle to the passage of the blood exists, medicine can often do nothing for the permanent cure of the hæmorrhage that it produces. For the time, the most effectual means are cool air, cold water or ice applied as near as convenient to the seat of bleeding, iced drinks, perfect quietude, and the avoidance of all stimuli; the body should be placed in that position in which blood may gravitate from the affected part, and if there be any indication of plethora or accelerated circulation blood should be drawn from the arm to an amount to be determined by the circumstances of the case. In many cases great benefit results from exciting the vessels, of and near the part, to a copious secretion of the usual fluids, as in some cases of hæmatemesis by administering purgatives. If astringent remedies be deemed advisable, and in many cases they are highly useful, the acetate of lead will generally be preferable, and next to it the different vegetable compounds of gallic acid. [ASTRINGENTS.] The treatment of the peculiar class of hæmorrhages from alteration of the blood is considered under FEVER, &c. Bleeding from the nose is treated under EPISTAXIS. (J. F. D. Jones, *On Hæmorrhage and the Ligature*; T. Watson, *Cyclopædia of Medicine*, art. 'Hæmorrhage.')

HÆMORRHOIDS (from *αἷμα* blood, and *ῥέω*, to flow), varicose tumours of the veins of the rectum. [ANUS, DISEASES OF THE.]

HÆRETICO COMBURENDO, WRIT DE. [HERESY.]

HAGUE, ALLIANCE OF THE. [TREATIES, CHRONOLOGICAL TABLE OF.]

HAIL, HAILSTONES, HAILSTORMS. The conversion of the aqueous vapour which is an essential constituent of the atmosphere, by the depression of its temperature, either successively into water and ice, or immediately into the latter without the sensible intervention of the former state; and whether in the atmosphere itself, or on the ground, or against the surfaces of bodies resting upon it or extended into the air, presents several subjects for philosophical investigation, all of them having important relations to the welfare of man and of the various beings of organic nature he associates around him, as well as to the operations of human life. Water in the solid state is produced from the atmosphere in several ways, and in different forms. When a portion of the vapour in the air at certain elevations freezes, by the sudden reduction in temperature of its entire mass, it becomes converted into innumerable separate congeries of minute perfect crystals of ice, which are called flakes of snow; when that in contact with solid bodies forming part of the surface of the earth, or immersed in the atmosphere, becomes sufficiently lowered in temperature by their loss of heat by radiation, hoar-frost appears; and under other physical circumstances we shall now proceed to describe, another and distinct form of atmospheric ice is produced, termed HAIL.

Sir John Herschel has stated his views of the philosophy of this subject in the following terms: after relating the observation, during a balloon ascent, of the temperature of 46° Fahr. at the height of 12,000 feet, and that of 22° only, or 24° colder, at the same elevation in the descent, a heavy fall of snow being then and there in progress, he says:—"It is evident that this arose from the condensation of vapour at that level, and that, from the intrusion of some current, a mass of intensely cold air had been introduced, which, finding vapour near saturation, converted it into snow. It is equally evident," he continues, "that had the latter condition prevailed, not at the level in question, but at a somewhat higher, where the condensation might have been into *rain* very near the freezing point, the drops in descending would have been frozen solid, and fallen as *hail*. It might have been so equally, had the precipitation been so copious as to allow the coalescence of a great number of minute particles in a nascent state into drops frozen together instanter, since there is good reason to believe that the solid form is never assumed without transition through the liquid, however momentary.[*] The generation of hail seems always to depend on some such very sudden introduction of an extremely cold current of air into the bosom of a quiescent, nearly saturated mass. Hailstorms are always purely local phenomena, and never last long. They often mark their course by linear tracks of devastation, of great length and very small breadth. In the hailstorm of July 13, 1788, which passed across France from south to north, two such tracks were marked, of 175 and 200 leagues in length respectively, parallel to each other, the one four leagues broad, the other two, and separated by a tract five leagues in breadth in which only rain fell. A similar character is very common, though not to such an extent. Such linear hailstorms are always attended with violent wind, sudden depression of the barometer, indicating a great commotion in the air, and probable mingling of saturated masses of very different temperature. . . . . . Great hailstorms are often preceded by a loud clattering and clashing sound, indicating the hurtling together of masses of ice in the air. The recent experiments of [Professor Faraday and] Professor Tyndall on the re-uniting of broken ice by 'regelation,' or a sort of welding, fully explain the formation, under such circumstances, of large masses of ice of irregular forms in this aërial conflict." (*Meteorology*, 'Encyc. Brit.' vol. xiv.)

The following account, extracted from the celebrated 'Climate of London,' by Mr. Luke Howard, F.R.S., of a hailstorm as observed at Plaistow, in the county of Essex, near the metropolis (the scene of his first series of meteorological observations), on the 19th of April, 1809, affords an instructive example of the local phenomena of such storms:—"The day had been sultry, like some preceding ones, and overcast with clouds, which during the afternoon gave evident demonstrations of an approaching discharge of electricity. Large and deep *cumulo-strati* were ranged side by side, mingled with the *cirro-cumulus* and *cirro-stratus*, the whole having that peculiar, almost indescribable character, which these charged conductors assume when wrought up to the highest state of electric *tension*. About five in the afternoon, being at the laboratory, and perceiving a continued roll of thunder, with vivid lightning approaching from the south, and the appearance of a heavy shower in that quarter, I anticipated a storm of no common violence. We were proceeding to take measures for the safety of some glass utensils, when in an instant there opened upon us a volley of hail of such tremendous force, as in ten, or at most fifteen minutes, demolished most part of the skylights and south windows in the neighbourhood. These *icy bullets*, some of them a full inch in diameter, were discharged almost horizontally from a cloud to the windward, and in such quantity as to be drifted in large masses under the walls. Whether borne by the impetuous blast that came with them, or carrying the air thus before them, I could not determine, but such was the velocity of their motion that in many instances a clear round hole was left in the glass they pierced; and one large pane (which I saw) had two such perforations distinctly formed, the glass otherwise whole. The water in the river, lashed by the hail and raised by the wind, resembled a cauldron boiling violently, rather than waves with breakers. The electrical discharges were incessant, approaching with the cloud and passing off with it: . . . . This sudden irruption over, it rained for a while moderately. The wind was at first E., then S. during the hail, then W., then E., then W. again. About seven, the clouds all at once put off their stormy character . . . . . The remainder of the evening was calm and pleasant. A person who was on the road *from London to Bow* (probably not two miles off) during the storm, informed me that he experienced nothing but continued thunder and lightning, and *very heavy rain*, the latter appearing luminous on the ground on each side of him, which it often does in heavy storms. It was evident from other circumstances that the hail was bounded in a western direction by the village of Bow, and it reached eastward from thence only about three miles. Its course appears to have been from S. to N., over Blackheath, Bromley, Plaistow, West Ham, and so up the country between the rivers Lea and Roding." The amount of damage occasioned by the hail in this case is mentioned in the sequel of this article.

Many other accounts of hailstorms, and remarkable falls of hail, and of hailstones of remarkable character, at various periods, in England and other countries, are distributed through the 'Climate of London.'

In the article 'Hail,' in Brande's 'Dictionary of Literature, Science, and Art,' it is stated that "Hail usually precedes storms of rain, sometimes accompanies, but never or very rarely follows them, especially if the rain is of any duration. The time of its continuance is always very short, generally only a few minutes, and very seldom so long as a quarter of an hour." The writer of the article referred to further remarks, that "the clouds from which hail is precipitated appear to be of very considerable extent and depth, inasmuch as they produce a great obscurity. It has been remarked," he adds, "that they have a peculiar gray or reddish colour, and that their lower surfaces present enormous protuberances, while their edges exhibit deep and numerous indentations." Other characters of these clouds have just been noticed.

Single hailstones have generally a crystalline structure, radiating from a centre if large, forming spherical, oval, or rounded masses, often marked out (on making a section,) into concentric layers, like the rings in the section of the trunk or branch of a tree. The form is often conical, with a rounded base, when they appear to consist of fibres meeting at the apex, but there is reason to believe that these are portions of spheroidal concentric-laminar concretions. They fall from the size of small peas, or much less, to that of an egg, an orange, or a man's head, and weighing from a few grains up to fourteen pounds and upwards. Very frequently hail falls of which each separate stone is, or originally was, a regular tetrahedral crystal of ice, generally with convex faces, apparently owing to the tendency of crystals belonging to the monometric system of crystallisation to which ice in part belongs, to assume curved forms. Often, these have an obvious concentric-laminar structure, and they are often degraded into a conical form by their solid angles and edges becoming rounded by partial melting during their fall. Some large hailstones of concentric structure have a tetrahedral nucleus, the polyhedral having been gradually converted during accretion into a spheroidal solid. As indicated above, the concentric-laminar is also a fibrous structure in hail as in hæmatite and other terrestrial minerals. In the 'British Mineralogy' of the late eminent naturalist-draughtsman James Sowerby, a work through which are scattered many valuable facts, is an excellent plate of a mass of tetrahedral hailstones, with separate figures of the constituent crystals and their structure. Sir J. Herschel has cited from Dr. Thomson's 'Introduction to Meteorology' a remarkable example of large hailstones of a radiated structure, but such as to evince that the particular stone examined had been formed in passing through two distinct regions of condensation in the air. He also cites from Dr. Buist the observation that in India the hailstones are from five to twenty times larger than the average magnitude of those in England, often weighing from six ounces to a pound, being seldom less than walnuts in size, often as large as oranges and pumpkins. The storms in which they are produced are almost always accompanied by violent wind and rain, thunder and lightning, and are frequent in the delta of the Ganges, especially in the low country within fifty miles of the Bay of Bengal.

Sir J. Herschel, also, after alluding, as above, to the effect of regelation in producing masses of ice in the air by the consolidation of aggregated hailstones, remarks, that "such are recorded to have fallen of almost fabulous magnitude," of which, but with great caution, he proceeds to recite several examples. The effect of the process of regelation (or to adopt the recent correction of Professor James Thomson, of that of *melting and regelation*) in converting congeries of hailstones into masses of ice is indubitable, but we are in need of sufficiently authenticated statements of the actual fall of such masses. We appear not to have any account of such a phenomenon by a qualified observer, and it is to be believed that in many instances a mass of ice really produced on the ground by the consolidation of hailstones which have fallen within a small area and heaped one upon another, has been supposed to have actually fallen ready formed. The following case from Dr. J. D. Hooker's 'Himalayan Journals' will illustrate the view now taken. On the 20th of March, 1849, at noon, a violent hailstorm coming from the south-west, occurred in the Terai, or damp forest-tree region, intervening between the plains of India and the Himalaya mountains, in this locality the Sikkim Himalaya. The hail was of "a strange form, the stones being sections [sectors or segments] of hollow spheres, half an inch across and upwards, formed of cones with truncated apices and convex bases," aggregated with their bases outwards. The fall of the large masses was followed by a shower of the separate conical pieces, and that by heavy rain. "On the mountains this storm was most severe: the stones lay at Dorjiling [of which place the mean temperature in March is 45° Fahr.] for seven days, congealed into masses of ice several feet long and a foot thick, in sheltered places. At Purneah, fifty miles south, stones one and two inches across fell, probably as whole spheres." Mr. Howard quotes a notice of a hailstone fallen in Hungary in 1803, which is stated to have exceeded the strength of eight men to lift it. This, he remarks, recognising (as far back as 1833) the *fact* as well as the principle of what is now

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[* On this subject see a paper by Mr. Brayley, 'On the probable existence of but two States of Aggregation in Ponderable Matter,' Annals of Philosophy, New Series (for September, 1826,) vol. xii. pp. 195–200.]

termed regelation, was doubtless "what is called 'an ice-board' formed by hail agglutinated in a hollow, by partial fusion on the surface, the whole freezing again by the intense cold within." The largest hailstones are stated to be of very rugged and irregular form, resembling portions of a great sheet of ice broken into pieces. An American observer, the Rev. D. A. Clark, cited in the 'Climate of London,' saw in the heat of summer, hailstones about one-fourth or three-eighths of an inch thick, and of sufficient diameter to hide a shilling, almost every one of which was perforated in the middle, as if it had been held between the fingers till thus melted. When the perforation was not complete, there was in every case a tendency to it. These were probably of the concentric spheroidal laminar structure, in which the central portions were incomplete. Mr. Howard has himself described a freezing shower which fell at Plaistow on the 19th of January, 1808, and which glazed the windows, and encrusted the walls, and encased the trees, the garments of passengers, and the plumage of birds. A portion being received on a sheet of paper was found to consist of hollow spherules of ice, filled with water; of transparent globules of hail, and of drops of water at the point of freezing, which became solid on touching the bodies they fell upon. As it is stated that the thermometer exposed from the windows indicated 30·5°, the temperature of these drops must have been below the freezing point, their solidification taking place, agreeably to the property of water in that condition, on the agitation of their particles occasioned by their impact on the surface upon which they fell. Had the process of freezing proceeded further before the fall of the shower the hollow spherules filled with water would have become ordinary hailstones with a cavity in the centre.

The electrical character of showers of hail has already been alluded to, and is well exemplified by the following account, given by Mr. Howard, of one which fell, with many others, in different parts of England, on the 19th of April, 1807, at Plaistow. Being carefully examined throughout, it presented the following phenomena: When the cloud discharging it—of course a *nimbus* [CLOUD]—"was on the horizon, N.E., and the shower behind it, the pith-balls of the insulated electrical conductor [of Mr. Howard's fixed apparatus for investigating the electricity of the atmosphere] remained in contact. When the extremity of the upper surface of the inverted cone of cloud had arrived in the zenith, they opened *negative*, and diverged slowly to full two inches, at which time pretty strong sparks were drawn from the conductor. During the remainder of the approach of the shower, they gradually closed again. At the moment when the latter [the shower] began to touch the observatory, they opened *positive*, diverged more speedily, and the apparatus gave strong sparks for a considerable time *positive*. As the cloud drew off to the S.W. this change gradually ceased, and the balls opened again *negative*, diverging gradually as before, then converging, and lastly were left a little charged *positive*." In all this, as Mr. Howard points out, we see the natural effects of the high positive charge in the column of falling hail, which may probably have been six or seven miles in diameter, and which appeared to be surrounded with a negative area, extending into the dry atmosphere about three miles in every direction. This very considerable quantity of electricity, and that of some intensity, was conveyed by an amount of hail comparatively insignificant; for when melted into the rain-gauge, together with that of several previous showers, it did not produce more than a hundredth of an inch of water in depth. It is an example of the fact we shall have to consider elsewhere, of how powerful an electrical charge ice is capable of receiving.

Saussure, as cited by Mr. Howard, attributed the greater or less prevalence of hailstorms in particular localities of the Alps to the relation of their electricity to that of the neighbouring mountains, the clouds or storms being either attracted or repelled by them, according as the electricity is similar or opposed to that of the mountains. Borgo Franco, in Piedmont, he had been informed, was peculiarly subject to the calamity of hailstorms; and it has often been observed, he states, that in other plains bordering on high mountains, at a certain distance from the mountains, hail is much more frequent than in places that lie somewhat nearer or more remote. There are distances, too, Saussure adds, that seem privileged, where hail very seldom falls. On an estate on the river Arve, not quite half-a-league from the foot of Mount Salêve, there had not been within the memory of man any considerable fall of hail, the stormy clouds passing always nearer to the mountain or at a greater distance from them.

Arago ('Meteorological Essays,' transl. into English, pp. 106–108) mentions some instances in which the aqueous precipitations from the atmosphere during thunderstorms, whether liquid or solid, have been observed to be luminous, one of which is the luminous rain during a hailstorm already cited from the 'Climate of London.' Among them is one recorded by Lampadius, who was informed by some miners at Freyberg that the small hail which fell during a thunderstorm on the 25th of January, 1822, was luminous when it reached the ground. These cases are doubtless to be explained by the high electrical charge which everything acquires during some thunderstorms; there are experiments with electrical apparatus in which corresponding luminous phenomena are occasioned.

The practice appears to have originated in the last century of making fires on the ground, and of discharging artillery and otherwise exploding gunpowder, on the approach of storms, for the purpose of dissipating them, and especially of preventing the formation or the fall of hail. Arago (loc. cit. pp. 212–218) has given an account of this practice, of the efficacy of which he considers that there is no sufficient evidence, if even the tendency of the evidence is not to show that continuous discharges of artillery may induce local thunderstorms. On the other hand, the experience of the Marquis de Chevriers, in preserving his lands from the ravages of hailstorms by the explosion of boxes of gunpowder, which he caused to be fired on the neighbouring heights on the approach of a storm, while the villages in the vicinity frequently experienced their baneful effects, does not appear to have been sufficiently considered by that philosopher. There are some grounds for believing, also, that the particular conditions of the atmosphere which result in the formation of hail may be counteracted by fires. Matteucci, the eminent Italian physicist, whose electrical researches continue to enrich science, informed Arago that there is a parish near Cesena, in Romagna, throughout the extent of which, for seven miles round, the peasants, by the curé's advice, place at about every 50 feet heaps of stone and brushwood, which they set on fire when a storm is seen approaching. This practice had been in force for three years, during which time the parish had not suffered either from thunderstorms or from hail, although it formerly suffered much every year from hail, and the neighbouring parishes had continued to do so during the period. "Three years," Arago remarks, however, "are not a sufficiently long period of time to allow of any definitive conclusion as to the preserving influence of large fires. The experiment is being continued, and the public will not fail to be informed of the results."

The principle of insurance has been applied to indemnify persons for the very heavy losses sometimes occasioned by these meteorological phenomena, both by the Royal Farmers' and General Insurance Institution and by a society connected with the Norwich Union Insurance Company. The uncertainty which exists in reference to the occurrence of these frequently calamitous storms in any particular locality, and the circumstance that, while no human sagacity can foresee or prevent them, it is utterly impossible to produce them by fraud, appear to render such casualties peculiarly fit, so soon as observation and experience shall have established accurately the average risk, for the application of a principle which has long been applied to casualties of a nature less uncertain, more easily provided against, and which afford greater opportunities for deceit and imposition. The Hail-storm Insurance societies have published chronological lists of the most remarkable hailstorms in this country during the present century, which present an array of destructive calamities far exceeding what might have been expected from their rarity. It is curious also to observe that they appear to have increased in frequency of late years. In one case, which we select solely from the more circumstantial way in which the details are given, many farms of corn were (on the 14th of July, 1824) literally destroyed in Hertfordshire, Middlesex, and Essex; the damage done upon a space of 3487 acres in the last-mentioned county alone was estimated at 14,574*l.*, or about 4*l.* 3*s* 7*d.* per acre, upon an average. It is stated that this was the third time within a period of thirty years that the crops in the north-western part of that county had been destroyed in like way. During the great hail-storms in the months of July and August, 1843, by which immense damage was done in Cambridgeshire, Norfolk, Suffolk, Essex, Hertfordshire, Berkshire, Kent, Oxfordshire, Bedfordshire, Gloucestershire, and Yorkshire, several cases of individual loss amounted to upwards of 2000*l.* The breakage of glass in windows and skylights, and more especially in conservatories and hothouses, is one of the most frequent injuries inflicted by hail-storms, the masses of ice which fall being sometimes sufficient to demolish the wooden framework also. Such extraordinary cases of devastation will be fully accounted for if it be considered that, as it is stated in a paper issued by the Farmers' Insurance Institution, on the authority of Leslie's 'Elements,' "hailstones having a diameter of two inches," a size which has been exceeded in several well-authenticated cases, "will fall with a velocity of 113½ feet in a second, or more than 1¼ mile in a minute." In the hail-storm of the 19th of May, 1809, Mr. Howard's account of which has been given above, it is estimated that 200,000 panes of glass were broken in the immediate vicinity of London alone, besides great damage being done in fields and gardens, and the foliage and branches of trees being cut off. An equal number of panes is supposed to have been broken in the northern suburbs of the metropolis on the 30th of July, 1826. In the denser parts of the metropolis itself less damage appears to be done on such occasions, probably because the vast column of heated air always rising from it alters the local atmospheric condition requisite for the production of large hail.

Hailstones of from six to eight or nine inches in circumference are frequently mentioned as having fallen in this country, in the lists referred to, which are compiled from contemporary publications; and on the 3rd of August, 1824, when the eastern part of Suffolk was visited by a violent hail-storm, by which fowls and game, as well as glass and crops, were extensively destroyed, the ice accumulated in some places to a surprising depth. In many cases a considerable extent of ground has been covered to the thickness of several inches. It is worthy of remark how very large a proportion of the destructive storms are recorded to have occurred in the months of June and July. Without noticing the cases in which two or more storms which occurred about the same time are alluded to as one, which would render this proportion yet more remarkable, the cases recorded in the above-mentioned lists occurred as follows :—

In the month of	January	0
,,	February	1
,,	March	2
,,	April	3
,,	May	7
,,	June	10
,,	July	17
,,	August	4
,,	September	2
,,	October	0
,,	November	0
,,	December	0
		46

The copious lists of hailstorms published by the Farmers' Insurance Institution, which gives references to authorities, and in many cases minute details of the damage done, appeared in the advertising sheet of the 'Farmer's Almanac' for 1845.

Mr. Howard remarks, in agreement with the results in the table just given, that hail is of rare occurrence in the winter, in England; if we except a sprinkling of small opaque grains which in the fore part of the night indicate the approach of a low temperature, and are found on the frozen ground, and on the ice of the ponds in the morning.

Mr. Alfred R. Wallace, in the account of the climate of the valley of the Amazon, appended to his 'Travels' on that river, cites an authentic account of a fall of hail on the Upper Amazon; a remarkable occurrence, he observes, at a place only three degrees south of the equator, and about two hundred feet (only) above the level of the sea. Children were out at play, and brought the hail to their parents, astonished at a substance falling from the clouds which was quite new to them and so remarkably cold. [Ice; Meteorology; Snow.]

HAINAULT SCYTHE. [Harvest.]

HAIR-MANUFACTURES. There is a considerable amount of industry bestowed upon human hair and the hair of certain quadrupeds, in the production of manufactured articles. Some of their uses depend upon the felting properties of a few kinds of hair [Felting; Hat Manufacture]; some upon the great strength of the fibre; and some upon the beautiful gloss of which it is susceptible. Human hair and horse-hair may be taken as the two chief materials for these manufactures.

Human Hair.—The hair-trade is a much more important one than would usually be supposed. It was stated in the 'Quarterly Review' a few years ago (No. 184) that London alone imports more than 100 cwts. of human hair annually, chiefly for making perukes and false curls. The mere clippings would not suffice; there must be a regular *harvest* of hair. A German has had the patience to count the number of hairs in an average adult female head (probably among his own countrywomen), and finds it to be 110,000,—the blonde being most numerous but finer in substance; the red least numerous but coarser. The light hair imported by or for the hair-workers is brought mostly from Germany, by a Dutch company whose agents periodically visit London; the dark hair more usually comes from France. Some years ago, light golden tresses were much in favour, and the German hair had a good market; but now French hair is more used. Young women in England, who have beautiful tresses, are sometimes urged by poverty to part with them for money to the hair-workers; but in France it is a regular system. There are hair merchants in Paris, who send agents in the spring of each year into the country districts to purchase the tresses of young women, who seek to cultivate an annual crop with the same care as a farmer would a field crop. The agents frequent fairs and markets; and have with them a stock of handkerchiefs, muslins, ribbons, &c., which they give in exchange for the hair. So sensitive a barometer is commerce, of slight changes in the value of exchangeable goods, that the agents know the hair of a particular district to be worth a few sous more per pound than that of a district thirty or forty miles away: a fact which naturalists would have been long in finding out. It is estimated that 200,000 lbs. of hair are purchased at each spring harvest. The price paid is about five francs per lb. on an average; but choice specimens fetch much more. The agents send the hair to their employers, by whom it is dressed and sorted, and sold to the hair-workers in the chief towns at about ten francs per lb. That which is to be made into perukes is purchased by a particular class of persons, by whom it is cleaned, curled, prepared to a certain stage, and sold to the peruke maker at twenty to eighty francs per pound. The peruke maker gives it the form which, as is well known, commands a very high price; a peruke is often sold for double its weight in silver. Both of the hair itself, and of perukes and other articles made of hair, France supplies a considerable quantity to England and the United States.

Besides the making of perukes, false curls, &c., hair-jewellery, so called, is another of the minor manufactures from human hair. Bracelets, armlets, lockets, brooches, earrings, and other articles for personal decoration, are made either wholly of hair, or of hair in combination with other materials. No hair-harvest is necessary for a supply of materials; the ordinary clippings are sufficient. The hair goes through numerous manipulations on a small scale. It is laid straight to prevent entanglement; cleaned with warm water and soda; dried on a soft towel; gently drawn between brushes; and sorted into different finenesses and lengths. By the aid of small leaden plummets, pieces of strong thread, and a work-table with peculiar marks and holes on its upper surface, the hairs are made to twist or curl or knot round one another, something in the manner of pillowed lace; a pattern marked on paper or pasteboard being placed on the table immediately beneath the work. For making such small articles as lockets and brooches, advantage is taken of the facility with which hair curls up when a heated iron is applied to it; it depends upon a gradual application of this heated iron to produce the required degree of curvature in the curl. The Great Exhibition in Hyde Park contained specimens of hair-work, representing portraits, trophies, temples, &c., as remarkable for patient industry as for defective taste.

Horse-hair, &c.—Various manufactured articles in horse-hair possess qualities which could not be found in any other substance easily obtainable. The horse-hair differs greatly in length and colour. Some of the white hair from the tail of Russian horses is as much as forty inches in length, possessing great evenness, elasticity, and gloss. Various other kinds, black, gray, and white, come to market in lengths from twenty to forty inches. Some kinds are fitted for the stuffing of sofas and other articles of furniture; while others have the requisite straightness and other qualities for the hairs of violin bows. Horse-hair cloth is woven of hair taken from the tail, mostly of Russian or South American horses. If the hair be naturally white, it admits of being dyed green, crimson, scarlet, &c. by carefully conducted processes; but black or gray horsehairs only admit of a black dye, and these are the kinds usually employed for horsehair cloth. Coloured hair-cloth, mostly made at Worcester and Sheffield, and at Paris, is extensively used in railway carriages and the saloons of steam-vessels, as well as in ordinary domestic furniture. In most cases the best hair-cloth only is made of horse-hair, the cheaper kinds being made of cotton, linen, or worsted; and the brilliancy and permanency of the colours depend as much on these fibres as on the hair. In the weaving of haircloth, the weaver uses a sort of hook-shuttle, which he passes between the threads of the warp from right to left; an assistant places a single hair over the end of the hook, and the weaver draws it through the warp. The process is a very tedious one, for each hair usually constitutes only one throw or thread of weft. Specimens of hair-cloth are made for conversion into carpets. Horse-hair is also made into ropes, sacks, and bags; one manufacturer has made it into muffs. For a cheap kind of stuffing, and as a material in mortar, cow-hair is much used as a substitute for horse-hair. We may mention here that horse-hair is imported to the extent of no less than 20,000 cwt. annually, and that half a million yards of horse-hair cloth are annually exported.

A substitute for hair has recently been introduced as a material for ornamental manufactures. Plaits and curls for head-dresses, as lately observed, are usually made of human hair; but the substitute consists of dyed hemp or flax, aloe fibre, plantain fibre, or China grass. The fibre, when dyed to the requisite colours, is combed or heckled until it presents a glossy surface. To make this into curls, a fixed holder is used, into which is inserted a rod slotted at one extremity. On this rod is placed a tube, slotted at one end and having a pin through it at the other. The fibres, in a damp state, are attached to the slot in the tube; and the tube being caused to turn, the threads assume a curled form, and are attached to the ends of the pin. The tube is then removed from the rod, and a heater inserted to fix the curl in the desired form. The curl is subjected to a final glossing and dressing. There are also attempts now being made to convert the tough fibre of a peculiar South American plant into a substitute for horse-hair.

One peculiar application of hair may be briefly noticed—that of the hair of rabbits and hares, carried on by the Russians. They work up the hair into a kind of felt; press or fashion it into bowls, dishes, plates, and other articles; and varnish it thickly. The materials thus made have the appearance of papier machée or varnished leather, and are strong, light, and durable.

HALLEY'S COMET. [Comets.]

HALO. [Meteors.]

HALOGENS. This term, derived from ἅλς, salt, is employed in chemistry to designate a class of bodies which form haloid salts with the metals. The halogens are chlorine, bromine, iodine, and fluorine, to which may be added the compound halogen cyanogen.

HALOID ETHERS. [Ethers.]

HALOID SALTS. [Salts.]

HAMATHIONIC ACID. [Euxanthic Acid.]

HAMBRO' BLUE. [Colouring Matters.]

HAMMER, POWER, AND STEAM. A reference was made from Forge to the present article. It will not be necessary to notice the hammer as a mere *tool;* but its importance as a *machine* has become such, that a few lines of description are here requisite.

Power-Hammer.—This name we will give to such hammers as can be worked with greater effect than by the mere muscular force of the hammerman, but with the aid of a power other than steam power. Such machines are now used in very great variety. Froming's forge-hammer, applicable to heavy castings, and also to the hammering of edge tools, files, and knives, may be set to work either by hand, water, or steam power; there is a driving shaft which, when once made to rotate by any source of power, effects all the rest, through the medium of a heavy hammer-head, guide-rod, cones, and a vertical spring; the mechanism is subject to modification, by which both the rapidity and the force of the blows can be varied. Hutton's power-hammer is raised by a band, strap, or chain, attached to a drum or pulley on an axis: the ends of the axis are connected with cones driven by bands from any source of power; when the blow is struck, the momentum is made to assist in elevating the hammer again; the axis has an endway as well as a rotary motion, by which one or other of the cones may be disconnected; a handle, commanded by the workman, determines the rapidity of the action of the hammer; and the arrangement altogether is such as to render this machine useful for hammering iron and steel between pairs of dies. Eassie's frictional action hammer, for small general work, can be worked by any continuously-revolving power-shaft, and can be brought up to an activity of a hundred and fifty blows per minute, with a very heavy hammer-head. Cotton's air tilt-hammer, worked by any source of power through the intervention of a shaft, fly-wheel, fast-and-loose pulleys, and cones, is provided with an air-cylinder, to regulate the force and rapidity of the blow; there is a piston-rod in the cylinder, with a piston at the top and the hammer at the bottom; and the admission of air into the cylinder is so regulated as to give complete command over the action of the hammer. Waterhouse's compressed-air forge-hammer, intended for general light work in a smith's shop, and working up to a rapidity of a hundred and fifty blows per minute, acts something in the same way as Cotton's. There are many other kinds; but these will suffice as illustrations of the whole class.

Steam Hammer.—This remarkable and powerful machine, without the aid of which many modern forgings in iron could scarcely by any possibility have been fabricated, is the invention of Mr. Nasmyth of Patricroft. Whatever modifications have since been introduced by other inventors, to him is due the main principle of the contrivance; and there is a good deal of justice in the prevailing appellation, 'Nasmyth's hammer,' as applied to the whole group. Mr. Nasmyth's first patent was taken out in 1842, since which date he has secured several others for minor improvements. A steam-hammer may be said to consist of a ponderous hammer which carries its own steam-engine with it; the cylinder, it is true, is fixed; but the piston always moves when the hammer moves, and a vertical rod connects them both. The action of the steam is *direct* upon the hammer-rod, without the intervention of any levers, fly-wheels, or cranks. The steam-cylinder is supported vertically, at a considerable height above the anvil. The hammer moves up and down in a true vertical plane by sliding in the grooves of a frame; it falls by its own weight, but is lifted by the force of steam driving the piston upwards in the cylinder. The steam is derived from a boiler placed at any convenient distance, through a pipe connected with the cylinder; and there is a complete apparatus of valves, &c., to regulate the admission and shutting off of the steam. As the hammer is in all cases very ponderous, it will fall heavily by its own weight; but the rapidity and force of this fall are susceptible of modification by the mode in which steam is admitted to act above or below the piston. The self-acting apparatus is the most beautiful part of the machine. A workman lightly touches a handle, whereupon the whole internal mechanism so modifies itself, that the hammer will in one instant give a blow sufficient to crush a bar of iron, and in the next a tap so light as to crack a nut-shell without crushing the kernel.

Very numerous minor improvements in steam hammers have recently been made by Kirk, Pearce, Eastwood, Naylor, Morrison, Farrot, Brown, Condy, Sykes, Wilson, M'Dowall, Rigby, and other inventors; but these need not be separately noticed. In some instances the hammer-block constitutes a sort of ram or plunger working within the cylinder, instead of a mass suspended from a piston-rod; some have the hammer, piston, and piston-rod all cast in one piece, to produce firmness in action, and to render the blows more effective; some are so arranged as to increase the fall, or space through which the hammer falls to the anvil—a space which has been made to reach full seven feet: some have the adjusting apparatus so exquisitely arranged, that even a child could vary the force between one blow and the next; some, not intended to equal Nasmyth's in range of application, are made simpler and cheaper for certain special kinds of work; some vary the power and rapidity of the blow without changing the depth of fall, whereas others vary their depth likewise; some economically lubricate the hammer-guides by collecting the grease and oil which fall from the stuffing-box; some are so planned that they can be employed, as occasion may require, in iron-forging, boiler-rivetting, or ore-crushing; some can be worked by compressed air or by steam at pleasure; some have the cylinder placed at the *side* of the hammer, to render less height necessary, and to give more firmness to certain parts.

Steam hammers are now made of enormous magnitude and power. The 50 cwt. 'Nasmyth,' at Portsmouth Dockyard is no longer a marvel of mechanical power. A steam hammer of 120 cwt. has been set up at the Bowling Iron Works, near Bradford. The shaft and crank forgings for the Great Eastern were made at the Lancefield Forge, in Glasgow, by the aid of a 120 cwt. hammer, with 6 feet stroke. Messrs. Morrison, of Newcastle-upon-Tyne, have made a steam hammer for the Russian government, in which the weight of the piston and piston-rod alone is 100 cwt. besides the weight of the hammer; and there is a working space 14 feet in width between the framing of the machine. The same engineers have made a steam hammer for the Mersey Iron and Steel Company, 21 feet high, 14½ feet working space between the framework, a piston 36 inches in diameter, a hammer of 140 cwt., and a total weight of 30 tons. New York possesses a steam hammer with a hammer-head weighing 150 cwt. It is indeed probable that the maximum of size and power has not yet been reached; if greater be required by manufacturers, greater can be produced by the machinists.

HANAPER OFFICE, one of the offices belonging to the Court of Chancery. Writs relating to the business of the subject, and their returns, were originally kept in a hamper, *in hanaperio;* and the others, relating to matters wherein the Crown was immediately or mediately concerned, were preserved in a little sack or bag, *in parvâ bagâ;* whence the distinction of the Hanaper Office and Petty Bag Office, both belonging to the Common-Law and of the Court of Chancery.

HAND-FASTING. [BETROTHMENT.]

HANDGLASS is a name given by gardeners to a portable glazed cover which they place over certain plants for one or two purposes; either to screen them from the effects of cold and wet without depriving them of much light, or to maintain around them an atmosphere of uniform humidity. Bellglasses differ from handglasses in no respect with regard to the purpose they are intended to serve, but instead of being composed of many pieces fastened together, they are blown into shape in a single piece. Glasses of this description are principally used to assist cuttings of plants in the process of striking root, or newly-planted individuals in establishing themselves in the soil. The rationale of handglasses seems to be this:—when cuttings or newly-planted individuals are exposed freely to the atmosphere, they part readily with the moisture they contain, in consequence of the specific power possessed by light, especially direct solar light, of causing perspiration. Under ordinary circumstances the moisture they part with is lost in space, so that it cannot be re-absorbed; and as the atmosphere of the plants or cuttings remains dry, perspiration will go on till the plant is exhausted or dead. The effect of a handglass is to invert this state of things; the moisture raised from the soil by evaporation, or produced by vegetable perspiration, necessarily accumulates beneath the handglass, the air enclosed by which gradually becomes more and more moist, and at last is saturated; this circumambient humidity is re-absorbed by the leaves, or branches, or soil, and thus restored to the plant which had lost it; in addition to which, perspiration itself necessarily goes on the more slowly in proportion as the air itself is charged with humidity. It may also be presumed that a handglass, or any such transparent cover, keeps the temperature in which the plant breathes higher than the external air, and thus stimulates the languid powers of vegetation. Some handglasses are made with either moveable tops, or with a division to open, so as to permit the escape of superfluous moisture or to admit air.

HAND-WRITING, PROOF OF. [EVIDENCE.]

HANSE TOWNS, called also the Hansa, and the Hanseatic League, a celebrated commercial confederacy, which took its name from a now antiquated German word, 'Hansa,' signifying an association for mutual support, in which sense it is used in two charters granted by king John, in 1199, to Dunwich in Norfolk, and to the city of York. The cities of Hamburg, Lübeck, and Bremen were in the middle ages the depositories of the manufactures of Italy and Germany, imported by sea, with which they supplied the northern countries of Europe in exchange for their raw produce. The wealth which they acquired by their commerce excited the envy and the rapacity of the princes and nobles; the imposition of new and the augmentation of old tolls were great impediments to trade, which was likewise rendered unsafe by numerous banditti and pirates who infested the roads and the neighbouring seas and rivers. But it is noticeable that while the towns of South Germany made this mutual protection almost their sole object, those of the north became in a great degree commercial leaguers also. It is not possible to fix the precise year of the establishment of the Hansa; and indeed it is probable that it was brought about by the German merchants who, from different towns, associated abroad. In 1245 the German merchants in England ordered that no German vessel should sail to Lyon, and the order being disobeyed by Rostock, and some other Westphalian ports, the merchants of those places were expelled from the body, which was in the enjoyment of certain privileges, until the transgression had been atoned for. Hamburg and Lübeck, there is no doubt, were the first towns to enter into an avowed union in 1210, to protect the commerce on the Elbe and the German Ocean: the two cities engaged to maintain ships and soldiers at their joint expense, to clear the road between the Elbe and the Trave, and the waters from Hamburg to the ocean, from robbers and pirates; and they further bound themselves to promote their commercial interest, and to defend their rights and privileges. The city of Brunswick, which was used by those two cities as a staple, joined the alliance in 1247; for while Italy was in possession of the trade of the Levant and India, a commercial route was opened, through the upper Palatinate, Franconia, and to the east of the Harz, by way of Brunswick to Hamburg. Other cities soon followed the example of Brunswick, and joined the league. The cities were divided into four classes, or quarters, the chief cities of which were Lübeck, Cologne, Brunswick, and Danzig; and the contingent in money, or armed force, was fixed for each. Lübeck was at the head of the league, issued the summons for the regular assemblies of the deputies of all the cities, which were held once in three years at Whitsuntide (the first in 1260), and also for the extraordinary assemblies, generally held once in ten years, in which they solemnly renewed their league, admitted new members, and excluded those that had not observed all obligations, compacts, &c. Lübeck also had the common treasury and the archives.

In 1261 they established in London their factory called the Steelyard; but German merchants had been in possession of it, or of an adjoining building known as the German Guildhall, for more than a century. An inquisition, quoted in Markland's 'History and Survey of London, of the 28 Henry III.' (1243-4), notices "the Gildhall of the merchants of Cullen" (Cologne), as being in Thames-street, near Dowgate. The number of the towns composing the League fluctuated; probably many which were not entirely free were not recognised as such by the sovereign in whose dominions they were placed, although admitted into the union. Among the principal towns, however, were Bergen in Norway, Berlin, Bremen, Brunswick, Colberg, Cologne, Cracow, Danzig, Deventer, Dorpat, Elbing, Frankfort on the Oder, Goslar, Göttingen, Groningen, Halberstadt, Halle, Hamburg, Hameln, Hanover, Hildesheim, Königsberg, Lübeck, Lüneburg, Magdeburg, Münster, Nimeguen, Osnabrück, Revel, Riga, Ruremonde, Stade, Stettin, Stralsund, Thorn, Venloo, Warberg in Sweden, Wesel, Wisby in the Isle of Gothland, Wismar, Zutphen, and Zwoll in Guelderland. Their four principal factories in foreign countries were at London, Bruges, Novgorod, and Bergen.

This powerful confederacy formed the first systematic plan of commerce known in the middle ages. In its factories a discipline approaching in rigour that of the monasteries was observed, which even extended to the celibacy of factors, clerks, &c. The power of the Hansa rose daily. The cities enjoyed in England the privilege of exporting goods duty-free, and in Denmark of importing duty-free. Their alliance was courted and their hostility feared by the greatest powers. The Hanseatic League defeated kings Eric and Hakon, in Norway, and Waldemar III., king of Denmark, in 1348; they deposed Magnus, king of Sweden, and gave his crown to his nephew Albert, duke of Mecklenburg; they equipped in 1428 a fleet of 248 ships, with 12,000 soldiers on board, against Erick, king of Denmark; and the League concluded commercial treaties with Denmark, Flanders, and England, where Henry III., in 1266, granted them great immunities. But when the roads and seas were no longer insecure; when princes began to be sensible of the commercial interest of their own states; and above all, when the discovery of America, and the way to India by the Cape of Good Hope, gave an entirely new form and direction to commerce, the Hanseatic League gradually declined. On July 25, 1598, the lord mayor of London dispossessed them of the fleet-yard in the name of the queen, who had withdrawn their privileges, and at the last general assembly at Lübeck, the deputies from the several cities appeared merely to declare their secession from the League. Hamburg, Lübeck, and Bremen formed an association in 1614, and remained free republics till December, 1810, when they were incorporated with the French empire, but on the deliverance of Germany in 1813 they were again separated from France, and with Frankfort-on-the-Maine are now called the free Hanseatic Cities of the Germanic Confederation. For a particular account of their connection with England, see STEELYARD. There are numerous works treating of this league. In English, vol. i. of Anderson's 'Deduction of Trade and Commerce' may be consulted. In German, the most important works on the subject are F. Sartorius's 'History of the German Hansa,' 3 vols., 1802–8, continued by Dr. J. M. Lappenberg, 2 vols., 1830–4; 'Die Urkundliche Geschichte des Hansische Stahlhofes,' zu London, 1851, containing much interesting matter relating to the Steelyard in Thames Street; and Mayer's 'Grosse Conversations Lexicon für die gebildeten Stände,' article 'Hansa,' contains a detailed history, with much of the internal constitution of the union.

HAQUEBUT. [ARMS.]

HARDNESS. A term applied to that condition of the force of cohesion in solids where the constituent molecules retain their relative position and resist the application of a force which tends to change the figure of the body. [ATTRACTION.] Hardness is not the same quality as density, since many dense bodies are much softer than lighter ones. Thus glass is harder than gold or platinum, and platinum is harder and denser than gold. Iron and zinc are lighter but harder than gold and platinum. Lead is the softest of the common metals; but potassium and sodium can be moulded between the fingers like putty.

Language is quite inadequate to express the various degrees of hardness in solids. Accordingly the mineralogist resorts to the artifice of selecting a number of well-known minerals as standards of comparison. These are arranged in the form of a scale, known as the *Scale of Hardness* in which each mineral is harder than the one which precedes it, so that each mineral admits of being scratched or having its particles displaced by the one that follows it.

SCALE OF HARDNESS.

1. Talc.
2. Compact gypsum.
3. Calcspar, any cleavable variety.
4. Fluor-spar.
5. Apatite (crystallised).
6. Felspar, any cleavable variety.
7. Limpid quartz.
8. Topaz.
9. Sapphire, or corundum.
10. Diamond.

In determining the hardness of a body, if it neither scratch, nor is scratched by fluor-spar, for example, its hardness is said to be 4, but if it should scratch fluor-spar and not apatite, its hardness is between 4 and 5. The degrees of hardness are numbered from 1 to 10.

The readiness with which some of the metals, steel especially, can be varied in hardness by heating, suddenly cooling, and then tempering, is of inestimable value in the useful arts. Another remarkable and useful property is in some cases developed in the production of alloys. Two metals, copper and tin for example, which are not separately remarkable for either hardness or elasticity, possess these properties in a high degree when combined in certain proportions, forming what is called *bell-metal*. [BELL-METAL.] Hardness is often accompanied by brittleness; but this may be lessened by heating and slow cooling, generally however at the expense of the hardness.

HARE-LIP, a malformation in which the lip is divided in one or more situations by clefts extending from its free edge towards its attachment. It has received this name from the resemblance which it bears to the divided upper lip of hares and other gnawing animals, and is one of the most common of the malformations by arrest of development. [MONSTER.] In the embryo, each lip is formed of four pieces which project separately from the jaws and unite with each other at different periods of fœtal life; but if by any circumstance their healthy development is checked, they remain permanently in the condition which they had at the time of its occurrence. The separate portions of the lower lip unite long before those of the upper, and fissure of the former is so exceedingly rare as to be seldom the subject of treatment. Of the portions of the upper lip, the two middle unite first, and then the two lateral to them; hence a fissure in the middle line is more rare than one on either or each side. Hare-lip may be single or double; that is, there may be one or two fissures—the one may be seated in the middle line of the lip, or opposite to the union of the two incisors with the canine tooth: if there be two, they will be found in the latter situation on each side. It may be simple or complicated with fissures of the gum or palate, which, being developed in an analogous manner, may be influenced by the same cause as the lips, though being earlier united they are less rarely affected.

The cure of hare-lip is important, not only for the uncouth deformity, but because sucking is prevented in infancy, and in later life the speech is affected. It is accomplished by cutting off quite smoothly the opposite edges of the fissure in its whole length, and then bringing them together and maintaining them in accurate apposition till, like the edges of a common wound, they have firmly united. For this purpose, after fixing the portion of the lip with forceps, each edge of the fissure is to be cut off with a knife, or a pair of knife-edge scissors, taking especial care that the wounded surface should be left of the same form and size in each. They are then to be placed in accurate contact by transfixing them with one or two hare-lip pins (according to the length of the fissure), and connecting them with silk wound round them in the form of an 8. These pins should be made of silver, with removeable steel points; the lowest should be passed through full two-thirds of the thickness of the lip, just above its vermilion border, taking care that it penetrates to the same depth in each portion, lest the edge of one should project beyond that of the other. The next pin should be passed midway between the lower edge of the lip and the nostril, and the remaining aperture should be closed with a suture or with sticking plaster. The intervening portions of the lip are now to be compressed by the silk wound about the pins, and additional security is afforded by placing a compress on each cheek, and there bandaging it firmly, so as to prevent the muscles of the lips from contracting and separating the cut edges. After the operation the part should be kept perfectly quiet and cool; in four or six days the pins and other dressings may be removed, and the edges of the wound, which ought to be completely united, will now need only to be secured by sticking-plaster.

When the fissure is double, it is generally advisable to operate first on one side, and when that is completely healed, on the other; but in some cases the whole may be done at once, by cutting off both edges of the middle and each of the lateral ones, and transfixing the whole by the same pins and sutures. In those cases in which a portion of the jaw-bone projects much, it may be sufficient to draw the teeth from it, and then the lip may be stretched to unite over it; but often it will be necessary to remove it by cutting-forceps, or to depress it by long-continued pressure. In all cases it must be remembered, that however wide the fissures may be, there is no loss of substance in the lip; its edges are drawn asunder by the muscles on each side, just as are those of a cut made in a healthy lip (which may indeed require the very same treatment).

The best authorities seem now agreed that after six or eight weeks, the earlier this operation is performed on the infant the better, only avoiding the period of dentition; for besides that very young children are likely to be quiet and asleep all day, and that the healing processes are then very active, it has the great advantage of enabling them to resort at once to their natural food by restoring the power of sucking.

HARLEIAN COLLECTION. [British Museum.]

HARMALINE $(C_{26}H_{14}N_2O_2)$ and *Harmine* $(C_{26}H_{12}N_2O_2)$ are alkaloids occurring in the seeds of *Peganum Harmala*. They are united with phosphoric acid. Harmaline forms yellow salts with the acids, and is transformed into a red matter by oxidising agents. The *harmala red* of commerce is the powder of the seeds. It is used in dyeing red, rose-colour, and pink. It is used in large quantities in Russia. Harmaline yields a number of substitution products, such as *nitro-harmaline*, *cyanoharmaline*, &c. Harmine forms colourless neutral salts which crystallise in long delicate prisms. Harmaline is converted into harmine by oxidation.

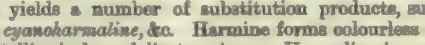
HARMINE. [Harmaline.]

HARMONIC PROPORTION. The reciprocals of numbers which are in arithmetical proportion are themselves said to be in harmonic proportion; thus

$$\frac{1}{a}, \frac{1}{a+b}, \frac{1}{a+2b}, \&c.,$$

is a series in harmonic progression.

A line AB is said to be harmonically divided when two points,



C and D, one within it and one on its continuation, are so placed that AC is to CB as AD to DB. In this construction, CD is an harmonic mean between AD and BD, or AD, CD, and BD, are as the reciprocals of terms in arithmetical proportion.

HARMONICA, also written Armonica (from the Greek word for harmony), but more familiarly *Musical Glasses*. Franklin in a letter to Beccaria, says that Mr. Puckeridge, an Irish gentleman, was the first who thought of playing tunes by collecting "a number of glasses of different sizes, fixing them near each other on a table, and tuning them by putting into them water, more or less as each note required; the tones were brought out by pressing his finger round their brims." Mr. Delaval, F.R.S., constructed a set according to the above plan, and showed them to Franklin, who endeavoured to improve the arrangement by mounting a number of glasses on an iron rod by means of a perforation in the bottom of each glass. The glasses partly fitted into each other without touching, and were tuned by grinding, and in this way three complete octaves were got into a small space. The rod was then fixed in a box, and being set in motion the tones were brought out by applying a moistened finger to the surfaces of the glasses. To distinguish the notes the more readily, the glasses were painted inside; each semitone white, and the other notes of the octave with the seven prismatic colours. Franklin describes the tones produced as being superior in mellifluous sweetness to anything he had ever heard before. The arrangement, however, was objectionable on account of its being liable to get out of order, so that the subsequent contrivers of musical glasses have resorted to the original method, which we may here state is nearly 200 years older than Franklin supposed, as may be seen in Harsdörffern's 'Mathematische und Philosophische Erquickstunden,' Zweiter Theil, Nuremberg, 1651. This work is a sort of elaborate "Endless Amusements," and contains a good deal that is really curious and useful, in some cases forestalling modern inventions, which have made more noise than that of musical glasses. Directions are given to take eight glasses of equal size, to tune them by means of wine, and with the wet finger "auf dess Glases Rand herumb fahren, so wirst du eine lustige Wein Musica haben."

Various methods of forming musical glasses have been introduced from time to time, all of them costly except that by Mr. Tomlinson, who selects soda-water glasses, finger-glasses, and tumblers of various sizes, and arranges them in a wooden case, fixing them by means of wooden screws, and bringing them to the same height by means of blocks of wood. The best way to select these glasses is to visit a glass warehouse, and arranging the glasses likely to suit, as to size, on a table, to sound on a flute the note required, and should the note be represented by any one of the glasses, it will speak by sympathy. The reader curious in the subject may be referred to Mr. Tomlinson's 'Student's Manual of Natural Philosophy,' 1838; which contains an elaborate article on musical glasses—their modes of vibration and acoustic properties.

HARMONICS. (Acoustics.) By the harmonics of a musical note are meant all those other notes in which the number of vibrations per second are twice, three times, four times, or any multiple of, the number of vibrations which produce the note in question. Thus the harmonics of a note which is sounded by 200 vibrations per second are those notes which require 400, 600, 800, &c., vibrations per second. The following explanation will be assisted by reference to Acoustics and Temperament. It presumes the reader to be acquainted with the fundamental mathematical laws of the scale. The harmonics of a note are infinite in number, theoretically speaking, and proceed by less and less intervals. And since every note may be considered as identical with any of its octaves, every harmonic has a corresponding note in any given octave. Denoting any key-note by C, and the octave above it by C′, there is no possible sound between C and C′ which is not theoretically either an harmonic of C, or as near to one as we please (which is equivalent to the mathematical proposition that a whole number, divided by a whole power of 2, may be made as near as we please to any given number or fraction).

But, in practice, not only is it impossible to produce any number of harmonics we please, that is, to maintain in vibration any aliquot part we please of a string or column of air, but even among the harmonics which we can produce we find a limit to the number of those distinct harmonics which deserve the name, etymologically considered. Some few of the first harmonics are melodious sounds, considered in relation to the key-note, but others are discordant, and find no place in the scale according to any system of temperament. We shall therefore, taking a given note, say C, simply mention the most important harmonics, and reduce them to their proper places between C and C′.

Let a be the number of vibrations per second which produce C; then $2a$ is well known to produce C′, so that the first harmonic of a note is its octave. The next has $3a$ vibrations, answering to G′; so that the twelfth, or octave of the fifth, is the second harmonic. The third has $4a$ vibrations, and answers to C″, the octave of the octave. The fourth harmonic has $5a$ vibrations, and gives E″, the double octave above the third, in the untempered diatonic scale. The fifth harmonic, with $6a$ vibrations, gives G″, the octave of G′ the second harmonic. In general, every harmonic whose vibrations are an even multiple of those in the key-note, is an octave to a preceding harmonic, and presents no new character. The sixth harmonic, having $7a$ vibrations, is an imperfect (being too flat) double octave to the flat seventh above the key-note, or B flat. This last note, in the common mode of tempering, makes $1{\cdot}77a$ vibrations per second; whereas the same note derived from the harmonic makes $1{\cdot}75a$ vibrations. The eighth harmonic, with $9a$ vibrations, is correctly D‴, or three octaves above the untempered major second. The tenth, with $11a$ vibrations, is a little too sharp for F‴, being $11a$ instead of $10\frac{2}{3}a$. The twelfth, with $13a$ vibrations, is a little too flat for A‴, being $13a$ instead of $13\frac{1}{3}a$.

The preceding summation is useful, as giving an account of the scale of all those musical instruments which consist of one unaltered pipe. These are the bugle, the French horn, the trumpet, and (but for its slide) the trombone; in all of which (except the last) no note can be produced except a harmonic of the fundamental note of the whole tube. Calling the fundamental note C (which however is not very easily sounded), the ordinary scale of these instruments is—

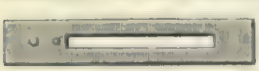
C C′ G′ C″ E′ G″ (B″ flat) C‴ D‴ E‴ F‴ G‴ A‴, in which B″ flat is too flat, F‴ is too sharp, and A‴ too flat. A short pipe however will not produce many harmonics; the bugle goes no further than G″, at least with common lips. Various contrivances have been introduced to extend and correct this scale; the keyed bugle, the use of the hand in the French horn, the pistons sometimes applied to the same instrument, and the short slide of the trumpet, to say nothing of the slide which is the principal distinction of the trombone, will suggest themselves to all who are acquainted with musical instruments. It will be seen under Horn that Mr. Sax has added other contrivances for the extension of the scale. In other instruments harmonics are much used, particularly in those of the violin class, and in the flute. The performance of Paganini upon a single string, which many years ago created great sensation among violin players, arose from an extraordinary power in producing harmonics. In the flute C‴ may be attained without much practice, as an harmonic of the fundamental note of the instrument; and we have heard of players who could produce D‴ and even E‴ in the same way. On the long strings of a piano-forte, as the fundamental note subsides, G′, C″, and E″ may be perceived; and we have heard, among the vaulted roofs of a cathedral, several of the harmonics of the notes sounded in chanting. For further information see the references in Acoustics.

HARMONIUM. This is one of a numerous family of instruments which owe their origin to the invention, or rather the revival, of the *free reed*. There are many claimants to this invention; but, as stated under Accordion, the Chinese were acquainted with it before its introduction into Europe, and the Chinese organ and the musical trumpet depended for their effects upon vibrating tongues of metal. The French, who are often as happy in re-inventing the inventions of other nations as they are undoubtedly clever in their own, claim the free reed; and so respectable an authority as M. Biot ('Précis élémentaire de Physique expérimentale,' Paris, 1817, tome i., p. 386, fig. 50) assigns the invention to M. Grenié, "habile amateur de musique." Biot says, in his usual perspicuous manner, "La languette est une lame de laiton parfaitement plane, et coupée en forme de rectangle, de manière à remplis exactement, ou plutôt presque exactement la face évidée de la rigole." This was in the year 1810; and two instruments were constructed, one of which was sent to the Conservatoire des Arts. In 1827 three free reed stops were introduced into the organ at Beauvais Cathedral, and in 1829 M. Sebastian Erard introduced a free reed stop into an organ built by him for the Tuileries. After this, the free reed gave rise to a number of new instruments, such as the *accordion*, Wheatstone's *œolina*, the predecessor of that exquisite little instrument the Concertina. Many attempts were made to improve the accordion by enlarging and completing its scale, so that it naturally assumed the form of an organ in which a free reed stop took the place of pipes

[Organ], and it was furnished with bellows worked by the foot. Such was the *seraphine.* Varieties of this instrument appeared under such frightful names as *æolophon, physharmonica, æolomusicon, poikilorgue;* also the *melodium* and *symphonium,* the *harmonium,* the *folding harmonium,* or *orgue de voyage,* which brings us to the subject of this article, in which all we can pretend to do is to give some idea of the mechanism by which the well-known musical effects are produced, referring the reader to his own good taste, or to that of his musical friends, in the selection of an instrument among the different clever makers who are warmly competing for public favour. To give a complete account of its mechanism, and the variations adopted by different makers, would require a volume.

It will be understood that the free reed differs from the beating reed in the reed-pipe of an organ in this,—that in the latter case a thin tongue of brass is made to beat on the flattened side of a tube, so as to cover and uncover alternately a slit through which the air passes into the pipe above. In this case the tongue is larger than the opening; but in the case of the free reed, the tongue is a little smaller than the opening, so that when a current of air is projected against it, the tongue yields so as to let it pass; but its elasticity forces it back into the opening, and its momentum carries it to an equal distance on the other side. In this way, so long as the current of air is maintained, vibrations are established, and a series of pulsations produced in the air which, if sufficiently rapid, will produce a musical tone. [Acoustics.] The vibrations of the reed depend for their rapidity on the thickness of the tongue at the free end in proportion to its length: if thick at the free end and thin at the fixed, the vibrations will be comparatively slow and the resulting note deep; if the tongue be thin at the free end and thick at the fixed, a higher note will be the result. The reed is tuned by scraping off a small quantity of the metal at the free or at the fixed end, as the case may be.

The accompanying figures represent the free reed as used in the harmonium: 1 is the brass frame containing the slit; 2 shows the reed in its frame and the method of fastening; and 3 its position in the instrument, the reed being a little below the slit when not in motion. This arrangement produces a more smooth and mellow tone than that of the beating reed, and has the grand advantage of not requiring a pipe, which is an indispensable appendage to the beating reed. The free reed has also a superior power of expression, and any given note, while preserving the same pitch, may be made loud or soft by varying the pressure of the wind; the greater the pressure, the larger the arc of vibration, and, consequently, the louder the note. The arrangements in the harmonium for varying the pressure of the wind, allow of *crescendo* and *diminuendo* effects being produced. There are also means for altering the quality of the notes, while preserving the same pitch, thus giving the varied effects of the organ with the portability of the piano-forte. Variation in quality is produced by making the reeds differ in size and shape.

1


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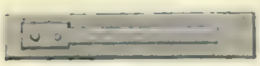

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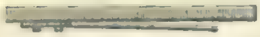
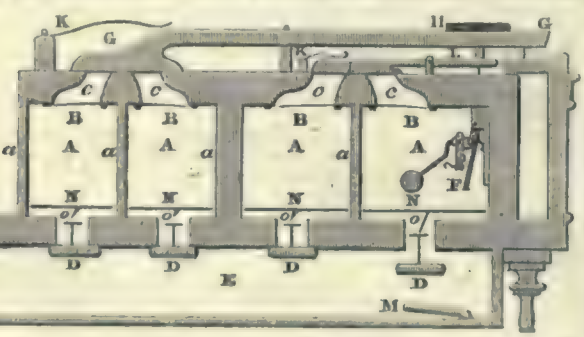


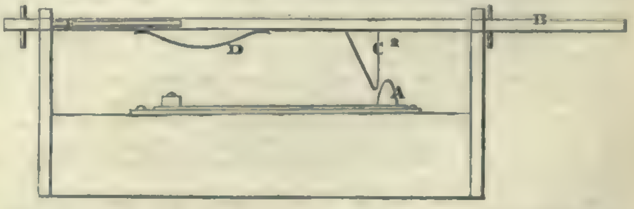
The accompanying figure, which we copy from Mr. Allen's pamphlet on the construction of the harmonium, will show the principal parts of the instrument. The notes are produced by wind which is furnished by means of bellows, worked by the foot, and forced through the valve M into the air-chest E, and thence through the cavities A A, in which the reeds are placed. These cavities occupy the whole width of the instrument, and are separated by partitions *a a*. B B are the reeds, of which there is a complete row or stop in each channel; G is one of the long or white keys, the further end of which forms a valve which closes two of the cavities, and is kept in its position by the spring K. Under and near the front end of the key is a lever, I, which covers two other cavities in the wind-chest, and is also held in position by a spring K. Thus it will be seen that the effect of pressing down any one of the keys is to open all four cavities; but whether the tongues in all of them be set vibrating or not, depends upon what stops are drawn out in front of the instrument. Connected with these stops are four steel rollers, N N, which open the valves D D, and thus admit air from the chamber E into the cavity A, and thence through the slit into *c*, and so out of the instrument after having vibrated the tongue. Each valve D is opened by a small piece of brass projecting from the side of the roller pressing on the piece marked *o*, and each valve is drawn up again into its place by a spring not shown in the diagram when the stop is pushed in.



The wind then being admitted through the slit from A into *c*, the tongue is made to vibrate, but it does so at first in a weak and inefficient manner, and time must be allowed for it to vibrate fully and freely. This is of course a serious defect in a musical instrument, a defect which in the case of the harmonium is overcome by what is called the *percussion action* in which the moment the key is pressed down, a small hammer rises, strikes the reed, sets it in full vibration which is then continued by the escaping wind. On pressing down the key, a button, L, on its under side, presses down a lever I, and this in its turn, forces down the hopper F, which sets the hammer in motion, as shown in the figure. The best harmoniums usually contain twelve stops or draw-knobs, the first of which, *cor Anglais* (bass), and *flute* (treble), is the principal stop. No. 2, *bourdon* (bass), and *clarionet* (treble), is tuned an octave lower than No. 1; No. 3, *clairon* (bass), and *fifre* (treble), is tuned an octave higher than No. 1. No. 4, *basson* (bass), and *hautbois* (treble), is tuned in unison with No. 1. When these four stops are used together, the power is very great. In Chappell's instruments the draw-knobs marked *forte,* communicate with slides which open apertures directly over the reeds, and thus increase the power. By drawing out the knob *grand jeu,* all the stops are opened at once, and great power produced. By drawing out the *expression* stop, there is an arrangement by which the power of any given note may be increased by pressing more forcibly on the foot-board, and in some instruments there is a draw-knob, marked *expression à la main,* by drawing out which the power of a note may be increased simply by pressing strongly upon the key. There is also the *sourdine,* and the *celesti,* for modifying the tone of certain stops.

The harmoniums best known in England are manufactured by Alexandre and Debain, of Paris, the latter maker claiming to be the original maker of the French instrument. In 1841, however, Mr. Evans of Cheltenham produced the *English harmonium,* with two claviers, and two octaves and a third of pedals. This instrument attracted much notice; but it was not brought prominently forward until early in 1859, when Mr. Evans became a steady competitor of the French makers. His object was to overcome the nasal and harsh tones, slow articulation, and other bad qualities of the instruments then in use; and he has succeeded in producing a fine instrument with a good diapason quality, and great rapidity of speech without any loss of power. He has also introduced a wind indicator for removing the difficulties usually felt in the management of the bellows. He has also patented a simple action by which is produced the C C C C (32 foot note) with instant speech; this is an octave lower than has ever been attained by the French instruments.

The means by which the percussion action is got rid of, and a similar effect produced of making the reed or tongue vibrate simultaneously with the depression of the keys or pedals, consists in having a toothed projection attached to a rod or connecting piece, which is moved by the lever extending from the keys; and the projection is so arranged that it works in a mortice formed in the connecting piece, and an extension of it forms a lever, the fulcrum of which passes through the connecting piece, the lever being retained in its place by a spring. When the key or pedal is depressed the connecting piece is moved, and the toothed projection comes in contact with another projection, attached to the free end of the tongue or reed, and as the spring yields, it passes the tongue freely, sets it in motion, and makes it instantly speak. The counter motion for restoring the key or pedal to its ordinary position is a spring or a weight attached to the connecting rod, or the connecting rod may be attached to a pedal or other projection acted on by the feet. The above figure is a side section of the mechanism at rest: A is the projection attached to the free end of the reed; in small reeds for the high notes this projection may be simply a protruding piece of bristle. B is a lever or jack, containing a mortice, in which is a smaller lever furnished with a tooth or projection C², this smaller lever moving on a centre the bearings of which are in B. D is the spring for keeping the smaller lever in position. For pedal action the reeds are arranged vertically, and a lever is attached to the end of the pedal with a connecting rod proceeding to the end of the jack and of the lever, so that when the jack is pulled down it may strike the projection the reverse way to that above described. The arrangement is, of course, applicable to concertinas.

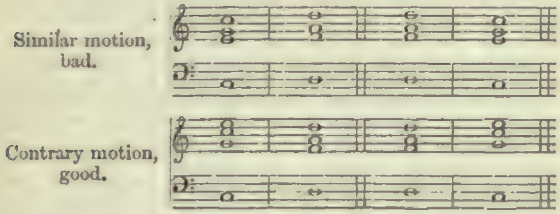


This action is *legato,* not *staccato,* like the percussion, and is therefore peculiarly adapted to pedal-playing. The toothed projection at the end of the vibrator is required in so short a tongue to produce the depth of tone.

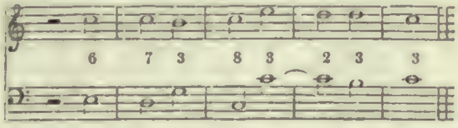
HARMONY (in Music), musical sounds simultaneously produced according to certain rules, forming a chord, or a succession of chords. The simplest harmony, namely the *triad*, or *common chord*, is the result of the vibration of all sonorous bodies, and the foundation on which much artificial harmony is built. Under the word CHORD the reader will find this matter further explained. M. Catel, a modern French theorist of great authority, has divided harmony into *natural* and *artificial*, including in the former all chords not requiring preparation; in the latter, all that are formed by retardation, suspension, &c. But we cannot acquiesce in this arrangement, for it places the chord of the seventh, which is the source of the three real chords of dissonance, in the same category as the triad, or the chord of nature, which of course cannot be admitted. It is true that the chord of the seventh requires no preparation—that is, the dissonant note need not be heard as a concord in the immediately preceding chord [DISCORD]; nevertheless this privilege cannot make natural that which is essentially artificial.

Harmony and *Counterpoint* are now practically considered as synonymous terms, and for some rules concerning the latter, as well as for examples, we refer to that word. [COUNTERPOINT.] To what has been said under the head CHORD, we also again call attention. Chords are the language in which harmony expresses itself, and the laws by which the one is governed regulate the other also. Besides the rules given under different heads in this work, we here add the few following:—

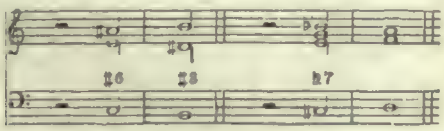
1. No two perfect concords, namely two 5ths or two 8ths, are allowed to succeed each other in the same progression, but are permitted in contrary motion; that is, when the one rises and the other falls. Examples:—



2. Most discords require to be *prepared*, and all must be *resolved*; that is, the dissonant note is to be first heard as a concord, and after *percussion*, or being sounded, must pass into a concord, generally by falling a tone or semitone. But sometimes the resolution is brought about by the base, as in the instance of the discord of the 2nd. Examples:—



3. It is in the nature of sharpened intervals to rise, and of flattened ones to fall; but extreme sharp intervals almost invariably must rise, and extreme flat ones as invariably must fall. Example:—



These examples will also show a reason for giving two names and appearances to that which is, practically speaking, one and the same note; though, theoretically, A sharp and B flat are different sounds.

4. In music in four or more parts, the parts should be dispersed, or separated, in a manner as nearly equal as possible: thus a more perfect symmetry is obtained, and a richer harmony produced. But with a view to some particular effect, a very different distribution of the parts is occasionally made.

5. As a general rule, every composition, whatever its kind, is to commence in its key; but as regards the termination, the rule is without exception, and peremptory: though sometimes the third is changed, from minor to major.

To enter fully into the subject of harmony would be to give a treatise on musical composition. The symbols of harmony—or certain figures, some written, some implied—will be explained under THOROUGH-BASE, an inadequate and unmeaning term, but so firmly fixed that it could not now be changed for a better. For the accompaniment of the scale—*La Règle de l'Octave*, as the French call it—a very important study when properly carried out, see ACCOMPANIMENT.

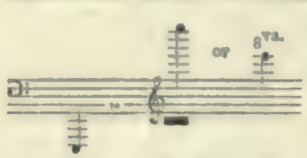
That the term *harmony* was not used in the same sense by the ancients as by the moderns, seems now to be generally admitted, but admitted without at all affecting the long-disputed and, we believe, undecidable question, as to the knowledge of counterpoint possessed by the Greeks and Romans, or compromising any opinion delivered or entertained on that obscure and perplexing subject. By Harmónia (ἁρμονία) the Greeks meant simply to express the proper relationship of one sound to another, the pleasing agreement of intervals in a melody, and nothing beyond. Though, however, they employed the word harmony in a very different sense from that given to it in later ages, it does not thence necessarily follow that they were ignorant of the high branch of the science to which we apply the term. That they played and sung in octaves is undeniable; and it is almost equally certain that they occasionally used simultaneous thirds, instrumentally and vocally. It seems unlikely, then, that so active, so ingenious, and musical a people, furnished with an abundance of many-stringed lyres, of double flutes, as well as other instruments, should not have discovered, even by mere accident, something of harmony, and have been led to investigate its nature and cultivate its practice. But on the other hand, if they were acquainted with the effect of combined sounds, and, as a sure consequence, had converted their knowledge to some useful purpose, they would almost certainly have left, among the numerous disquisitions and lengthened conversations on the subject of music which have reached us, some undeniable evidence of so important a fact.

HARP (heaꞃp, *hearp*, Saxon), a musical instrument which, under different forms and denominations, may be traced to the remotest ages. According to Holy Writ, Jubal, seventh only in descent from Adam, was its inventor; he "was the father of all such as handle the *harp* and organ," as Moses tells us. Notwithstanding the wonders related of Amphion's lyre, or harp, we are compelled to believe, judging from representations in sculpture and on coins, that the Greeks themselves did not so much improve the instrument as their writings would lead us to conjecture. But there now seems to be little doubt that the Egyptians brought the harp to a comparatively high degree of perfection: the fresco painting discovered by Bruce near the ruins of Thebes, which he thinks was executed by order of Sesostris, who reigned between fourteen and fifteen hundred years before the Christian era, exhibits a harp so much resembling that of the present day, in form, dimensions, and ornament, that it might, upon a hasty inspection, be mistaken for one of modern manufacture. He describes it as wanting the pillar, an omission, most likely, of the painter. "The back part," he says, "is the sounding-board, composed of four thin pieces of wood, joined together in form of a cone, that is, growing wider towards the bottom. . . . . . Besides that the principles on which the harp is constructed are rational and ingenious, the ornamental parts are likewise executed in the best manner. The bottom and sides of the frame seem to be veneered, or inlaid, probably with ivory, tortoise-shell, and mother-of-pearl, the ordinary produce of the neighbouring seas and deserts. It would be now impossible to finish an instrument with more taste and elegance." This account, among others by the same, was at first received with some suspicion; but later travellers in Egypt, among whom is Denon, have vindicated Bruce and confirmed his statements. Rosellini too, one of the best authorities, in his work, 'I Monumenti dell' Egitto,' &c., Pisa, 1832, has given coloured engravings of harps corresponding in nearly all respects with the instrument designed and described by Bruce, thus proving the great superiority of the Egyptian harp over every instrument of the kind known to have been in use among the Greeks or Romans.

Many learned persons, observes M. Ginguené, are of opinion that the Europeans are not indebted to the Egyptians for the harp, notwithstanding the resemblance of the instruments used by both the former and the latter; they believe that it originated in the north, that it was introduced into England, and subsequently into Ireland, by the Saxons and other piratical hordes from the Baltic. Martianus Capella found it among the northern tribes which overran the Roman empire in the fifth century. Jones, the Welsh bard, claims for his country the possession of a harp of twenty-six diatonic notes, so early as the beginning of the sixth century, and moreover adds that musical compositions proving the validity of his claim were extant in his time. But he offers no authority for the statement. The Irish were well acquainted with the harp from a very early period, and it appears probable that harps of the Egyptian kind were known in Ireland long before our æra. In Bunting's 'Historical and Critical Dissertation on the Harp' is an engraving and description of an ancient Irish one still in being, though in an imperfect state. It had in a row forty-five strings, and an additional seven in the centre, as unisons. Its form is not unlike that of the modern instrument, but the pillar is curved outwards, and in point of workmanship the whole is remarkable "both for the elegance of its crowded ornaments and for the general execution of those parts on which the correctness of a musical instrument depends." Its height is 3 feet 10 inches, and the longest string is 3 feet 4 inches.

The Welsh triple-stringed harp of the present day extends from G an octave below the first line in the base, to G or A in altissimo on the *right* side; and from G, the first line in the base, to the same upper notes on the left hand; the middle row consists of the semitones of the outward rows. Hence, if the outside rows be tuned in the diatonic scale of G, each parallel note being in perfect unison, the notes of the middle row are tuned a semitone higher; "that is, C is made sharp, &c., so that in modulating from the key of C to that of D, the performer introduces a finger between the C natural and D of the outside strings to strike C sharp, which is in the middle row."

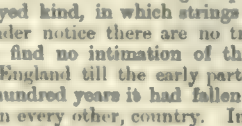
The harp, as a generally useful instrument, may be said to date its existence from the time when pedals were added to it. With these it is possible to modulate into all keys, and to execute any music suited to keyed-instruments. We are indebted for the present improved and nearly perfect state of the harp to the late M. Sebastian Erard, who, in 1794, took out a patent for a harp with seven pedals that rendered the chromatic scale. This was a single-action-harp, the pedals only effecting one change on the strings. In 1808 the same mechanist produced his double-action harp, the pedals of which have two actions. This last is tuned in the key of C flat. By fixing the pedals in the first groove the instrument is at once transposed into C natural; and by fixing them in the second groove it is transposed another semitone higher, into the key of C sharp. The compass of the harp thus improved is from double E below the base to E in altissimo; or—



But though the harp in this highly improved state may be used for the performance of any music written for the pianoforte, yet in executing compositions in which there is much modulation, the difficulty is of an extreme kind, and indeed unconquerable except by devoting more time to practice than ought to be bestowed on an accomplishment, however elegant and fascinating.

In the construction of the harp there are many ingenious mechanical contrivances which would repay the study of persons fond of such investigations: there is also much skilful workmanship required. The name of Erard is still one of power in connection with this instrument. At the Great Exhibition of 1851, Mr. P. Erard received the Council Medal for his pianofortes, and on "account of the great merits of his harps the jury included them in the award." Messrs. B. Jones are honourably mentioned for an improved triple strung Welsh harp, and a Spaniard named Gallegos received a prize medal for an ingenious specimen of *harp-guitar*.

HARPSICHORD (originally, and with some reason, written *Harpsicon*), a keyed musical instrument, in form the same as the grand pianoforte, but smaller, strung with steel and brass wires, two to each note, which were struck by *jacks* armed with small pieces of quill, acting as *plectrums*, and thus made to render a brilliant but somewhat harsh sound, wholly unlike that produced by the hammers of the piano-forte. The compass of the harpsichord did not at first exceed three octaves, but by degrees was extended to five, from double F below the base to F in altissimo: or—



All harpsichords had *stops*, which increased or diminished the string power: they also were generally furnished with a *swell*, or a means of opening and closing the lid: and many were supplied with two rows of keys, the upper acting on a separate set of strings, which gave a very soft sound, intended as an imitation of a muted violin, &c.

The period at which the harpsichord was invented is quite uncertain. It is not absurd to surmise that the organ speedily suggested some instrument of the keyed kind, in which strings were substituted for pipes, but of that under notice there are no traces before the 15th century. Indeed we find no intimation of the harpsichord having been introduced into England till the early part of the 17th century; and in less than two hundred years it had fallen into disuse in this, as well, we believe, as in every other, country. In 1838, Mr. Moscheles, wishing at his *Soirées Musicales* to perform some of the lessons of Scarlatti, Handel, and Seb. Bach on the instrument for which they were written, had great difficulty in finding, in the vast city of London, a harpsichord to enable him to accomplish his purpose. Several other stringed instruments struck by *plectra*, were, together with the harpsichord, superseded by the superior *action* of the PIANOFORTE.

HARQUEBUS. [ARMS.]

HARTIN ($C_{20}H_7O_2$). A white crystalline resin extracted from lignite.

HARTITE. A resinous matter very similar to *hatchetin*.

HARTSHORN, SPIRIT OF. [AMMONIA.]

HARTSHORN, the horn of the *Cervus Elaphus*, the hart, or common stag [DEER], which has a place in the pharmacopœia, because it contains less earthy matter, and more gelatine, than other bones. It is kept in the form of shavings, of which a sufficient quantity boiled in water yields a jelly suitable to convalescents, which may be flavoured with lemon-juice or wine, &c; but there is no proof that it is superior to jelly made from calves' feet. It is sometimes a useful addition to milk for young children, but it possesses no alkaline properties, and the further addition of a little lime-water is often necessary to fit it for irritable stomachs. The decoction of hartshorn is often used by brewers to clarify beer and other liquors, as being cheaper than isinglass (Pereira). The pungent volatile salt, called smelling-salts, retains the name of hartshorn from being originally obtained by distillation of this horn. [AMMONIA.]

HARUSPICES, a class of priests in ancient Rome, whose principal duty was to inspect the entrails of the victims which had been sacrificed, and thereby to foretel future events. They also interpreted various phenomena, such as lightning, earthquakes, &c. (Cicero, 'Cat.' iii. 8; 'Div.' i. 41.) This art, called *Haruspicina*, was derived from Etruria, where it is said to have been discovered by one Tages. (Cic. 'Div.' iii. 23.) The Romans used frequently to send their children to Etruria in order to be instructed in this art (Niebuhr), or as others read the passage (Cic. 'Div.' i. 41) caused a number of young Etrurians belonging to Roman families to be so instructed; and Etrurian haruspices often practised their profession in Rome. The duties of the haruspices in many respects resembled those of the augurs; but they were not reckoned so important, and they never acquired that political influence which the augurs possessed. [AUGURS.] They were formed into a college or corporation at Rome, of which the chief was called "Summus Haruspex," or "Magister Publicus." Their art fell into disrepute among the well educated Romans in the later times of the republic. Cicero ridicules their pretensions of foretelling future events, and relates that Cato used to say that he wondered how one haruspex could meet another without laughing. (Cic., 'Div.' ii. 24.) The Emperor Claudius wished to revive the study; and under his directions a decree of the senate was passed for that purpose (Tac., 'Ann.' xi. 15); but it probably produced little effect.

HARVEST is a most important period to the husbandman. When by his skill and industry the ground has been well prepared to receive the seed, and every circumstance has been favourable to the growth and ripening of his crops, he may be deprived of a great portion of his reward by an unseasonable time of harvest. Although the state of the weather be beyond his control, he may, by an attentive observation of the usual changes at particular periods of the year, anticipate its influence in any particular situation. The precautions which are necessary in a northern climate, where the fruits of the earth come late to maturity, would be superfluous in more southern latitudes. It is from the inhabitants of northern and mountainous countries that we are likely to learn the means of obviating the effects of an unfavourable season and a late harvest.

In those southern climates where the heat and drought are not too great for the growth of corn, the only care of the farmer is to procure hands sufficient to reap it. The heat of the sun and air soon dries the straw and hardens the grain. A spot is levelled in the field, and the corn is threshed out immediately, either by the tread of cattle driven over it, or by the flails of numerous threshers. The corn is winnowed and stored in granaries; and the straw is reserved till winter, when it forms the chief fodder of horses and cattle. In these regions the harvest is a continual feast; no ungenial weather disappoints the hopes of the husbandman. But in northern climates, where the harvest is later, and cold rains and storms are frequent in autumn, ingenuity is often taxed to save the corn from being entirely spoiled, after it has been severed from the ground; roomy barns are erected to secure it in the straw, till it can be threshed; and the joy of harvest is frequently interrupted by the anxiety which is the consequence of sudden changes of weather.

To lessen the casualties of harvest in a moist climate, the experienced husbandman endeavours to arrange the time of sowing each kind of grain, so as to ensure their coming to maturity in a regular succession. Thus he has more time to attend to the precautions of which experience has taught him the utility; and if the duration of harvest is longer, there is less danger of all his crops being spoiled by a wet season.

It was long the custom through the whole of the north of Europe to store all the produce of the farm into barns, especially the corn; and it was thought that as soon as the sheaves were collected under a roof, all danger was past. The increase of the produce raised on most lands by an improved system of agriculture gave rise to the practice of stacking corn in the open air, and securing it by a covering of thatch. It was soon found that the grain thus stored in the straw was better preserved than that which was in the barn; and the invention of stone, or cast-iron pillars, as supports for the frames on which the grain was stacked, not only secured it from the depredations of vermin, but kept it in a much drier state than when the stacks were made on the ground. This was a great improvement; and now, in the best managed farms, the only barns required are those in which the corn is threshed; and if there is sufficient room to hold the contents of one stack of the usual dimensions, it is all that is absolutely required.

The want of room in the barns was probably one of the reasons why the reapers were permitted to cut the straw half-way between the ear and the root, leaving more than half the straw in the field. Another reason also was the profusion of weeds which grew amongst the corn, and which retarded its drying, by retaining the wet much longer than the ripe straw. It was thought also that the seeds of weeds were thus prevented from mixing with the grain in the threshing, and giving more trouble in the winnowing. The usual prohibition against selling any straw also made the farmers less careful to secure the whole. The stubble was mown after harvest, and formed into broad walls, called in some places *haulm-walls*, round the yards where the cattle were fed in winter, for the double purpose of fodder and shelter. But it is evident that this practice is defective; there can never be too much straw to be converted into manure by the dung and urine of cattle, and what is left as stubble is much wasted before it is mown and carried into the yard. The seeds of noxious plants remain on the land, whereas they would be much more effectually destroyed if they were stacked with the corn. The subsequent separation of them is a very trifling additional labour where a winnowing-machine is in use. It may therefore be admitted as a general rule in reaping, to cut the straw as near to the ground as possible; this, if done by hand, is best done by an instrument called a *cradle scythe*, which mows the straw, and collects it so as to be readily gathered into sheaves.

The Hainault scythe has a very short handle, and is used with one hand, while the other collects the straw into a sheaf by means of a large hook at the end of a wooden rod. It is a most useful instrument, and greatly preferable to the fagging-hook in use in Middlesex and the neighbouring counties, where straw is valuable and sells at a high price. It cuts more straw at each stroke, and is less fatiguing to the reaper, because his position is nearly upright when he uses it. In many places it is not usual to tie up any corn into sheaves, except rye, wheat, and beans. Barley and oats are usually mown, raked into heaps, and carried into the stack or barn when dry, like hay; but this is a slovenly practice, which should not be recommended. With good tillage and proper manuring the straw of barley and oats will be strong, and of sufficient length to require being tied up into sheaves; and much less of the grain is shaken out and lost in this way than by the usual method.

The rapidly increasing, and soon to be universal, practice of harvest work will be to cut all corn by the reaping-machine, of which a description will be given in its place. [REAPING MACHINES.]

In rainy seasons it frequently happens that the sheaves remain a long time in the field before they are sufficiently dry to be carried and stacked. If the ears are not secured from the wet they become soaked, and the grain sprouts in the ear. This is a great loss; for sprouted grain is very inferior, and can only be sold at a low price. A little attention will often prevent the bad effect of rains. In some places six or eight sheaves are set up in a circle, with the butt-ends diverging, so as to admit the air to circulate among them; a sheaf is opened by spreading out the ears, and is placed inverted over the ears which lean against each other, forming a truncated cone. In others four sheaves thus placed are covered by other two, ears downwards, and the whole bound together by a band. Thus the butt-end of the top sheaf is the only part in which the rain can lodge: and the first sunshine will soon dry this; the rain runs off the sides of the inverted sheaves, and the ears, pointing downwards, will not long retain the wet.

When the stack is building, the butts of the sheaves are placed outwards, and project gradually over the sides of the frame, and over one another, so as to build the stack in the form of a bowl, with a cone or pyramid over it, according as the frame is round or square; this is carefully thatched with straw, and the outer surface is cut smooth by means of shears. This not only saves all the ears which chance to lie outwards, and which would have become the prey of birds, but it also prevents the rain from beating into the stack and injuring the corn. It may then be considered as safe.

Where there are no raised frames, and the stack is built on the ground, or on a bottom made of faggots, to keep it dry, a belt of plastering or stucco is sometimes laid, a foot wide, round the stack, about 18 inches from the ground, after the surface has been cut quite smooth and even. This contrivance is intended to prevent the rats from lodging in the stack, and it is very effective. A frame made entirely of iron, and supported upon iron columns, has lately been invented. It may be readily taken to pieces and put together again when it is wanted. The advantage of it is, that it is cheaper and more easily moved than any other; and it is very convenient for a temporary purpose.

Harvest is proverbially a joyous time, and one when hospitality is practised with more good-will than at any other season. The custom of giving a supper to the harvestmen and women, when the last corn is carried, has been observed from time immemorial; and it is much to be regretted that in many farms it is now omitted, or a mere gratuity is given instead. The community of good feelings which ought ever to exist between the master and his servants or labourers, is most effectually kept up by occasional friendly intercourse. The anticipation of this enjoyment was an incitement to exertions in the field; and the farmer was amply repaid the expense which the feast occasioned. The stimulus of strong beer is still applied at harvest, and frequently to such a degree as to defeat its own object. In some places the labourers have a certain sum in addition to food *to finish* the harvest, whether it is a longer or shorter time. In others they have the usual weekly wages, and a gratuity at the end, with plenty of beer so long as it lasts: accordingly as labourers are abundant or not, the price is less or greater. Many thousands of Irishmen still come over to England and Scotland in the time of harvest, and are of great use in finishing it in a short time.

The processes of harvesting the several grain and root crops are described in detail under their respective names. The above remarks apply generally to the cereal grains. The period of ripeness at which each should be cut is important, as affecting the ultimate quality of the sample. The last process of ripening seems to consist in the growth of the outer skin of the seed, which is the bran of the miller. An early cutting of wheat is important, as hindering an excessive growth of this bran. Oats need to be cut early, as, if ripe, a great deal of the grain is lost in windy weather. Barley, which for malting purposes needs to be all of one ripeness, is secured in that condition by allowing it all to become dead ripe, which is indicated by the downward pointing of the ear. Beans and peas are better cut before becoming dead ripe, as their straw is then more valuable for fodder.

HAT MANUFACTURE. Hats are made of wool, fur, silk, straw, and many other substances. The material chiefly used in making straw hats is wheat-straw plaited in strips and sewed together in the required form, in the manner described in STRAW PLAIT MANUFACTURE. Silk hats are composed of a form made of chip, stiffened cotton, or felt, and covered with woven silk plush or shag, fashioned to the required shape and drawn over the form. There are three descriptions or qualities of hats made of wool, namely, beaver-hats, plait-hats, and felt-hats. Each of these has the body composed of felt: the first has a covering or nap of beaver; the second, a nap of the fur of the musk-rat, or the neutria, or some other fur of small value; and the third kind is without a nap. It will be sufficient to describe briefly the chief points of difference in these.

Beaver Hats. The curious art of *felting* is believed to have been brought to Western Europe by the Crusaders, who found the tents of their enemies covered with that substance. Wool in the yolk, that is, with the natural grease, will not felt; and it is necessary to the process that it should be well scoured, when the fibres being brought together have a tendency to mat or interlace. This tendency is so strong that it is not possible to spin woollen yarn without previously oiling the wool. Hats of the very finest quality are made with lamb's-wool imported from Spain or Saxony, and the fur of English rabbits. The nap is composed of the fur of the beaver and neutria and the down from the back of the English hare mixed together. To form the body of the hat the wool and rabbit's-fur are separately *bowed* in the manner employed for freeing cotton from its seeds [COTTON.] The two substances (about 2¼ oz. for one hat) are next bowed together until they are intimately mixed; after which the mass is spread evenly, covered with an oil-cloth, and pressed, first gently and afterwards more strongly, by which means the fibres will become tangled or interlaced. A very loose and imperfect felt is thus produced, by reason of that peculiar property which is described under FELT AND FELTING, and the cause of which may be understood from the annexed magnified view (*fig.* 1) of a fibre of fur. The next process is to cover the felt with a triangular piece of damp brown paper, and then to fold it in a damp cloth and work it well with the hand, pressing and bending, rolling and unrolling it, until the interlacing or felting is much more perfect, and the mass becomes compact. The felt thus prepared is in the form of a large conical cap; it is taken to the wide brim of a boiler charged with water and beer-grounds and a small quantity of sulphuric acid. In wine countries the lees of wine are substituted for beer grounds. This mixture is kept nearly to the boiling point. The workmen, having the palms of their hands protected by a covering of thick leather, lay the felt on the margin of the boiler, and then proceed to sprinkle it with the hot liquor and to work it about with their hands; by this means it shrinks and becomes more compact. It is then dipped into the boiler and worked, first with the hands, and next by the help of a rolling-pin, which admits of more force being used; and this process is continued until the felt no longer contracts. Considerable skill is required in thickening that part which is to form the brim. After being worked about in this way for some time, it is found that the cap, by the continued influence of heat, moisture, pressure, and friction, has been reduced to one-half its former dimensions, but doubled in thickness.

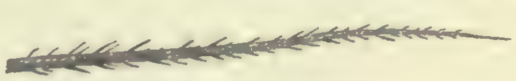


Fig. 1.—Fibre of beaver-fur magnified.

The next process is that of stiffening. The substance employed for this purpose is a varnish composed of several gums and resins, a solution of which is applied by means of a brush to one side, and sometimes to both sides of the felt. After this it is stoved, by which the whole substance becomes duly impregnated with the resin.

We have now to attend to the outer covering or glossy surface. To form the nap of a hat, one-half or three-fourths of an ounce of beaver, and some other less costly fur, are required. The fur has previously been carefully prepared. It is cut from the pelt or skin by a beautiful machine adverted to in the article FURRIERY, and shown in *fig.* 2;

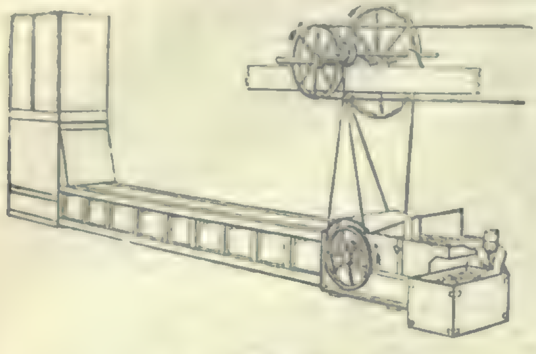


Fig. 2.—Fur shearing machine.

after which it is sorted by the machine shown in *fig.* 3, described in the same article. When ready, the fur is bowed and imperfectly felted in the manner already described, and shaped the same as the body to which it is to be applied, but a little larger. The body is softened by immersing it in the boiler; after this the nap is applied and worked as in felting, until the required union is effected between the two bodies. A narrow strip of beaver is felted round the inside of the cap, to form the underside of the brim. During the felting, the fibres of fur become driven in between the fibres of the felt body, and firmly interlocked.

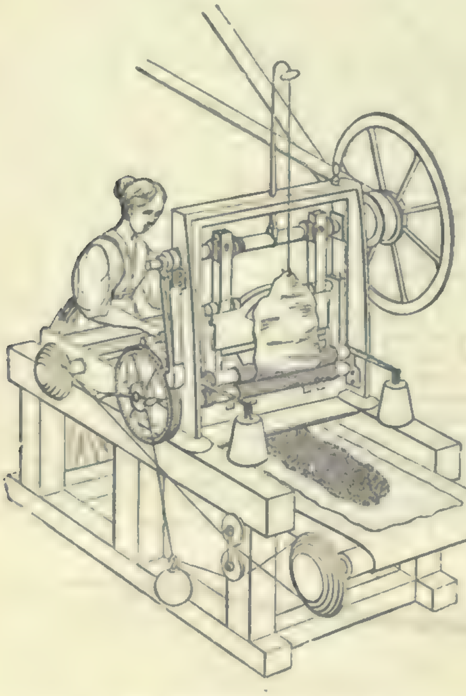


Fig. 3.—Fur separating machine.

The felt thus covered is in the form of a cone, and must be brought to the cylindrical shape in which it is worn by means of a wooden block of the requisite form. This operation, which is called blocking, is performed by working it with the hand on the block to which it is tied. The hat is then combed and sheared; after which it is dyed in a bath composed of water, logwood, sulphate of iron, verdigris, and gall-nuts, in which the hat is boiled during some hours; it is then drained and dried. After this it is softened by steam, the crown is strengthened by placing in it a disc of scale-board, and linen is pasted over this. The nap is raised, and a uniform direction given to its fibres by means of warm irons and hair brushes. The last processes are binding and lining; when the hat is ready to be worn. A good beaver hat passes through the hands of not fewer than twenty or twenty-five workmen during the process of manufacture.

Plaited and Felt Hats.—The beaver hats, just described, although the best results of the hatter's art, are very little worn at the present day; their commercial importance is therefore small. In every way the use of them has lessened. Originally the foundation, as well as the napping, was made of beaver fur; then there was a substitution of fine wool and coarse fur for the foundation; then a mixture of cheek beaver and common beaver for the best fur, as a napping; and lastly, a combination of a very small portion of beaver with neutria, musquash, hare's fur, and wool. About the year 1830 it was estimated that a million beavers were annually killed to supply the hat-trade in Europe; but in 1860 it is believed that little more than one-twentieth of this quantity is thus used. The *plaited* hats, in which coarse and cheap fur are employed instead of costly beaver, are made nearly in the same way, and have been equally affected by change of fashion. The revival of the old *felt* hats, or the use of such hats by persons who would formerly have scorned to wear them, has given a great impetus to this particular branch of the manufacture. Here no fur is employed. Wool, of a greater or less degree of fineness, according to the price to be charged, is felted into a compact body; and this body is either blocked into the regular hat shape, or is made to assume one of the many varieties of slouch or 'wide-awake' forms. It may be mentioned here that in America felt hats are now made by machinery.

Silk Hats.—These have become by far the most important article in the manufacture, so far as concerns extent of production. Silk is wholly incapable of *felting*, and therefore cannot be applied to a hat in the same way as wool or fur. A silk hat consists of a non-felted body covered with a non-felted hood of silk plush. Willow, cane, chip, stiffened cambric, horsehair, mohair, and many other substances are employed for the body or foundation. The body is made by shaping round a block, and using a substance of extra thickness for the brim. A varnish cement is used to join the various parts; and a resinous stiffening composition is laid over the outer surface. To aid the adhesion of the silk plush to the body, the latter is coated with a peculiar varnish, which, being softened by a heated iron after the plush is laid on, causes the two to adhere closely. The fixing of the plush is the most difficult part of the manufacture. The silken fabric must not only be made to adhere in every part, but the seam or joining up the side of the hat must be rendered as imperceptible as possible. The plush is in the first instance sewn by women into the form of a hood or covering for the hat; but there is no sewing at the meeting-edges up the side; they are brought together, pressed down with a heated iron, and the silk shag brushed over the joint. Their junction can always be seen in a silk hat, however cleverly made. The large increase in the manufacture of silk hats within the last few years, has resulted chiefly from the use of a waterproofing composition previous to the application of the plush; the elastic gums, when dissolved in naphtha, impart a body or substance to the foundation, which enables the makers greatly to reduce the quantity of material employed in making it, thus at once cheapening the hat and making it more light and elastic. The same quantity will now work up into more than twice as many hat-bodies as were producible by it twenty years ago. Plush is largely made in England for covering silk hats; but the best, for the so called 'Paris hats,' comes from France, whence nearly 200,000 lbs. of black silk plush are yearly imported for this purpose.

Cork Hats, &c.—The novelties introduced or proposed within the last few years in the hat-manufacture are very numerous; but we can only glance slightly at some of them. The lightest hats made are those in which the foundation is of cork, cut into very thin sheets by a sort of veneer-cutting machine; but though light, they are not yielding, and not well suited to maintain their shape. One novelty in felt hats consists in producing the shape by a kind of die and counter-die, one of which forms the convex and the other the concave side; the dies are heated by steam, and the combined heat and pressure force the felt to assume the desired form. A somewhat similar method is that of forming a hat in one piece without joining; the felt, cloth, or other material, after being dressed with an adhesive solution, is stamped into form between a heated mould and a heated plunger; the hat might even receive a pattern or device on its surface, if the mould were engraved or embossed; and a waterproofing solution might be applied either before or after the stamping. One inventor proposes to employ a former or core of perforated metal; this former rotates in front of a trough containing wool or hair; a revolving fan sucks the air out of the former, and draws the fibres from the trough until they are deposited in a layer on the perforated metal, where subsequent processes cause them to felt together into a hat-body. Some hats are made with a complicated system of springs in the foundation, to facilitate the folding up of the hat into a flat form for placing under the arm or on a seat. A contrivance having a similar object in view has been introduced, consisting in cutting the body quite through, at the lines intended for the creasing; the edges are then cemented by covering them with a thin strip of India-rubber, leaving the edges a little way apart. A suggestion has been made for using palm-leaf, or the Brazilian grass-plait, as the foundation for a hat; the material to be plaited to something like the necessary form, then shaped on a block while moistened by hot water, then strengthened with tapes at the edges, and then stiffened and rendered waterproof; it is conceived that such a hat, coated with silk plush, would be light, soft, easy, and durable. Some hats are rendered 'ventilating' by cutting a circular hole in the foundation, and hiding it with the silk plush; while others exhibit a complicated structure of the brim and sides for the attainment of this end.

The export of hats now amounts to about 130,000 dozens annually, nearly all to the British colonies.

HATCHETIN. A fossil resin found in the lignite of Wales. It is colourless, fusible, and volatile; and is probably identical with *ozokerite*. It has the same per-centage composition as olefiant gas, but is doubtless a mixture of several chemical compounds.

HAUTBOIS. [Oboe.]

HAWKER. [Pedlar.]

HAWKING. [Falconry.]

HAZEL. *Economical Uses.* The hazel is best known for its *nuts*, which are consumed in enormous quantities. From Spain alone there are usually exported 30,000 or 40,000 bags in a year, of four bags to the ton. Besides being eaten simply as a fruit, the nuts are sometimes peeled in warm water, and used as a component in dishes like blanched almonds; or converted into a kind of chocolate; or made into bread; or pressed to yield an oil little inferior to almond oil. The wood of the tree is not large enough for building purposes; but it is used in cabinet-making, and in the manufacture of a number of small articles; it is close, even, and pliant, but does not take a good polish. Some of the roots yield curiously-veined pieces, eagerly sought after for ornamental purposes. The smaller branches and twigs of the hazel are more useful than the main trunk, on account of their toughness and flexibility; they are largely employed for crates, hurdles, props, wattles, walking-sticks, fishing-rods, whip-handles, ties for faggots, springes for birds, thatch-fastenings, &c. Evelyn, among other mention of the uses of this tree, said: "The use of the hazel is for poles, spars, hoops, forks, angling-rods, faggots, cudgels, coals [charcoal], and sprynges to catch birds; and it makes one of the best coals, once used for gunpowder, being very fine and light, till they found alder to be more fit. There is no wood which purifies wine sooner than the chips of hazel. Also, for withes and bands; upon which, I remember, Pliny thinks it a pretty speculation that a wood should be stronger to bind withal, being bruised and divided, than when whole and entire." Hazel-rods, cut of equal size and varnished, form good materials for rustic garden-seats and flower-baskets; and many ornamental devices may be produced by using some peeled, and the rest unpeeled. A laborious but uncommendable attempt has been made to produce a kind of mosaic picture, by interlacing differently-coloured hazel-rods.

A peculiar abuse, rather than a use, of the hazel, is described under Divining-Rod. The old herbalists, too, had singular notions about this plant, which modern medicine has by no means confirmed.

HEAD, INJURIES OF THE. From the many peculiar and important features which they present, injuries of the head have properly received a separate consideration in all systems of surgery. For not only is the brain so essential to life that even its least injury must be regarded as serious, but the parts around and guarding it have many peculiarities. The skull, composed of two thin layers of bone, much exposed to external violence, and protected from it by only slight coverings, is extremely liable to fracture, and it is covered by a very dense and tightly applied membrane, the pericranium, of which the injuries and diseases exhibit all the peculiarities of those of other fibrous membranes. By the free communications of its vessels with those of the similar membrane (the dura mater) lining the interior of the skull, and less directly with those of the brain, disease is very liable to spread from the pericranium to these more important parts; and it is itself covered by firm unyielding muscles and tendons, under which disease is always prone to extend widely. The injuries of the head are best considered as they affect the parts enclosing the brain or the brain itself.

In mere bruises of the scalp two circumstances are worthy of notice. A vessel of some size may be burst without the skin over it being wounded, in which case a most copious effusion of blood takes place, raising up the scalp from the skull, and producing rapid swelling of the whole of the upper part of the head. It needs however no particular treatment; no incision should be made into it, for if cold wet cloths be diligently applied, the blood will be again rapidly absorbed. If the effusion of blood from the bruise takes place between the pericranium and the skull, the former is raised into a tumour, with sharp defined edges, and yielding to pressure in a manner so similar to that of fracture with depression of the skull, that the most experienced surgeon might be deceived and induced to apply the trephine, but for the rule that it should never be employed except in cases in which the brain itself is implicated.

A common superficial wound of the scalp needs no particular treatment. It should be closed with sticking-plaster after the hair around it has been shaved off, and it should be kept cool; but to guard against mischief to the adjacent parts, the patient should avoid all stimuli, and all exertion of either body or mind, till it is completely well. Not unfrequently a violent oblique blow will strip off a large flap of the scalp so as even to denude the bone. In cases of this kind, the part, after being carefully cleaned, should be accurately replaced: if absolutely necessary, a suture may be inserted to ensure more exact adaptation, and the rest should be closed by adhesive-plaster; the head around, being shaved, must be kept perfectly cool; the patient must be placed on low diet, take aperient medicine, and remain quiet; on the first appearance of general excitement blood must be taken from the arm, and by leeches applied round the wound; under this treatment many cases get well with almost singular rapidity; but if irregularities be permitted, serious consequences may ensue even from the slighter injuries.

One of the most common of these sequels of injuries of the scalp is erysipelas of the head and face. It generally occurs in persons of an unhealthy habit, in hard drinkers, and in the full and plethoric. It commences about the third or fourth day after the injury; the patient begins to complain of headache and a feeling of general illness; he has a shivering fit, followed by nausea, thirst, and restlessness; a quick and hard pulse, and a thickly-coated tongue; he cannot sleep, and is perhaps slightly delirious. Soon after these symptoms have commenced the head and face feel very hot, and become red and swollen, appearances which increase, and after a day or two are accompanied with an eruption of small blisters, full of yellow fluid. There is no pain on touching the parts; but by the great swelling the eyes are often closed, and the features almost obliterated. Active reducing measures should, as a general rule, be early employed, and continued, if the disease does not yield, as far as the patient's strength will permit; and purgatives, with small doses of mercury, should be given, for the liver is very generally affected. After a period of from five to eight days the inflammation in most cases subsides, the cuticle scales off, and the wound, which had assumed an indolent unhealthy appearance, acquires a vigorous aspect, and rapidly heals. But in some cases the cellular tissue thus affected suppurates and sloughs, the scalp is separated, and there is profuse discharge from the wound. One or two incisions should in such case be made into the sloughing part, to admit of the free separation of the sloughs; but even with this the disease will sometimes spread and prove fatal.

Another affection which sometimes follows injuries (and especially punctured wounds) of the external coverings of the skull is inflammation and consequent extensive suppuration in the loose tissue connecting the tendon of the muscle covering the top of the head with the pericranium. The general symptoms of fever are in these cases less severe than in erysipelas; the scalp is less hot and swollen, but more painful and very tender; the face is never affected. After a few days of general illness, a feeling indicating a collection of fluid may be perceived over some part of the head; and on making an opening into the swelling which has formed there, a quantity of matter may be pressed out of it from beneath a large portion of the scalp. When this affection is suspected to be coming on, leeches should be put on the head in large numbers about the wound, and cold diligently applied; but if matter should form, one or more free incisions should be made through the scalp to let it out, and the part afterwards treated like a common abscess.

In cases in which the bone has been exposed, the same general and local treatment should be employed. The scalp when replaced may at once unite to the bone; or if it do not, granulations may spring up from the surface of the bone and close the wound: in worse cases, the outermost layer of the skull may die, and require a tedious process for its exfoliation and healing; in the worst, the whole thickness of the skull may perish, and the dura mater be exposed. In all these cases the mildest treatment is requisite, but as the disease is extremely liable to spread to the interior of the skull, the general health should be carefully watched, and if any indications of mischief arise, general or local bleeding should be at once employed.

When the bone itself is injured, no active treatment should ever be adopted, unless there are evident signs that the brain is suffering from compression or any injury that may be mitigated. These fractures of the skull get well even more rapidly than those of other bone; and in some cases, especially in children, the skull may be forced in to some extent, but when it does not produce any derangement of the functions of the brain the injury will be repaired, and health perfectly restored. Cases of fracture of the skull in which the brain is not at first injured may be amongst either the most simple or the most dangerous in surgical practice—for the least intemperance or irregularity committed within some time after their reception may produce irreparable inflammation of the brain or its membranes.

Injuries of the dura mater (the membrane lining the interior of the skull) are of yet more importance, because they more immediately affect the brain. The dura mater is connected with the skull by a tissue in which numerous vessels ramify, and these may be ruptured by the jar from a blow which does not even break the skin. The blood that flows from them, accumulating between the dura mater and the skull, produces compression of the brain. The chief indication of this very dangerous accident having occurred is that the patient, who for some time after the blow had seemed only stunned, or had been even quite sensible, gradually becomes dull, sleepy, comatose, and at last totally insensible, just like one suffering from apoplexy. These symptoms supervene with a rapidity corresponding to the size and number of the vessels ruptured; the most rapid are those in which, by a blow on the side of the head, the main artery, supplying the dura mater and upper part of the skull, and which ascends just before the ear, is wounded. The only hope in these cases is to bleed the patient largely, to check the flow of blood in the head, and if that be not evidently beneficial, to apply the trephine wherever it is most probable that the blood may be found and removed. It must be confessed, however, that there is little prospect of doing good by trephining in these cases; it is seldom possible to decide at what part of the skull the blood is effused, or whether it may not be between the dura mater and the brain, or even in that organ itself. The symptoms in each case are the same, but the mechanical removal of the blood is possible only when the blood is immediately beneath the upper parts of the skull.

Instead of blood, purulent matter may collect between the dura mater and skull, and produce equally fatal results. This is indicated by the patient (usually some considerable time after the accident) complaining of headache, restlessness, and extreme languor; he has frequent irregular shiverings, his pulse is quick and hard, and he cannot sleep: if unrelieved by treatment, all these symptoms increase, and are shortly followed by delirium, convulsions, insensibility, or paralysis, which are no distant precursors of death. Early after their first appearance, a puffy, soft, but not very hot nor painful tumour, forms over the part struck. If this be opened, the pericranium will be found detached for some extent from the skull, which when exposed is seen to be dead, of a dull yellow colour, and covered by purulent fluid. In this case it may be expected that the dura mater is separated from the interior of the skull to the same extent that the pericranium is from its exterior, and the only hope of relieving the patient is to perforate the dead portion of bone with the trephine, and let out the matter collected between it and the dura mater, and which compressed the brain.

The brain itself may suffer injury either from blood effused in it by rupture of its vessels, from compression by fractured portions of bone being forced down upon it, from wounds, from concussion, or from inflammation, and its various effects following any of these injuries. The first need not here be particularly treated of; it does not differ in its symptoms from the cases of common apoplexy with effusion of blood [Apoplexy], and admits of no mechanical treatment. The second class comprehends the most important injuries of the head; those of "fracture with depression," as they are called, and those which occasionally happen in children, in which the skull is indented without being broken. The symptoms of such an injury are insensibility, generally in direct proportion to the degree of pressure; the breathing is slow, laboured, and snoring, and at every expiration the cheeks are puffed out and elevated; the pulse is slow and irregular; the pupil widely dilated and insensible to light; the patient neither feels nor moves, and lies as if in a fatal state of apoplexy. The part struck may of course present most varied characters: it may be *starred* from the centre of the blow, so as to have a shallow conical depression; it may be fissured, and one edge have passed under the other; or it and the scalp may be broken up confusedly, and the brain be protruding through the openings in them. It is worth remembering that the inner part of the skull may, in consequence of its brittleness, be much more widely fractured than the external, so that the degree of pressure on the brain is not always indicated by the depth of the indentation felt in the scalp. If unrelieved by treatment, the patient from the time of the accident grows more and more insensible; his pulse becomes more irregular, and he rapidly dies. The evident and indeed the only mode of affording relief is to remove the pressure from the brain, by exposing the fractured part of the skull by enlarging the wound in the scalp, or making a fresh one, and taking away or elevating all the portions of bone that are depressed. The mode of doing this will be determined in each case by the form of the fracture and other circumstances; in some it may be sufficient to remove the loose pieces with forceps; in others, to saw off portions with a Hey's saw, or to apply the trephine and raise the other depressed parts to their proper level with an elevator. These proceedings however must of course be limited to the cases in which the fracture is in a part within view; when it extends across the base of the skull no mechanical means are applicable, and recovery is therefore extremely rare. Such cases, and all others in which compression cannot be mechanically relieved, can only be treated like common apoplexy, by bleeding the patient, by cold sedulously applied, and by rigorous reducing measures. The after-treatment of cases in which the trephine or analogous means have been used is nearly the same as in wounds of the skull and soft parts; the edges should be brought gently together, and slight pressure employed to support the dura mater where it is exposed by the aperture in the skull: and the other usual precautionary and curative measures, as cold, local bleeding, &c., resorted to.

The immediate consequences of wounds of the brain vary greatly, and indeed unaccountably: in some cases a very slight injury is rapidly fatal, as in those (of which many are now recorded) in which a pointed instrument has passed in through the orbit, and produced almost instant death; whilst in others severe and extensive injuries, as from gun-shots, have been followed by serious symptoms at only a late period from their reception. In most of the cases where the dura mater is perforated, whether by wound or by ulceration, the wounded or exposed brain protrudes through the aperture in the form of a darkish dirty-looking fungous mass, called "Hernia Cerebri." Its surface discharges purulent matter abundantly, and often bleeds slightly: pressure on it, as on the brain itself, produces immediate insensibility; but the whole mass may be cut off without producing any pain or ill consequences. This is indeed the best treatment of it. If after having protruded to some distance it shows no disposition to decrease or to slough, it should be cut down to the level of the skull, and gentle pressure by compresses covered with the mildest ointment applied, so as to compensate, if possible, for the deficiency in the dura mater. Should the mass again sprout forth, the same treatment may be repeated. In a few cases the growth is checked, and the brain produces healthy granulations, which unite to the surrounding parts and skin over; in others the fungous mass sloughs and the remaining parts heal; but in the large majority the exposure of the brain and its irritation by surrounding parts produce such continued inflammation of it as proves fatal.

The last injury of the brain that needs particular notice is that called concussion or commotion. The exact nature of it is totally unknown; the name indicates only that which has been supposed, namely, a shaking or general disturbance of the minute parts of the brain. In its slightest degree it is merely a stunning, from which perfect recovery takes place in a few minutes; in its most severe, it is rapidly fatal; but even in these, a post-mortem examination discovers no alteration whatever in the structure of the brain. One of the most interesting points in surgery is the diagnosis of concussion from compression of the brain. As the latter seldom occurs without the former (for of course a blow which would fracture or indent the skull would violently shake the brain), compression has the symptoms of concussion, with the addition of some of the most severe which we have already mentioned. In concussion the patient is insensible only to slight impressions, for if he be loudly called to, he will wake up, answer a word or two, perhaps even rationally, and then relapse into the same state. If he be severely pinched or otherwise irritated he will withdraw the part so injured: he occasionally moves his limbs; he appears, in short, as if in a sound heavy sleep, like that of a drunken man. The breathing is not stertorous, but generally quite natural; the pupil is contracted and irritable; the pulse is sometimes unaffected, but in severe cases small and weak; there is nausea or vomiting, and the extremities feel cold. If the case is about to terminate fatally, the whole body grows rapidly cold, the pulse becomes irregular and weaker, the breathing short and interrupted, and the insensibility increases. In treating cases of concussion much caution is needed: it has not appeared that bleeding, which is the remedy popularly expected for all such accidents, has at all diminished its primary symptoms, nor has the contrary treatment by stimulants been more successful. The patient, while suffering from the immediate stunning consequences of the blow, should merely be kept quite warm in bed, and carefully watched; if the pulse grow weaker, the extremities colder, and the other symptoms of sinking seem increasing, stimulants are first called for, and should be given till he is completely roused to his former state; but if, instead of being depressed, he remain stationary, no active means of any kind should be employed. Cases are not rare in which, after remaining in a nearly insensible state, as if in a sound sleep, for four, six, or eight weeks, with only very slight temporary alterations, the patient wakes, complaining of but little inconvenience, and rapidly recovers. If instead of waking nearly well, he is observed to grow restless, to seem suffering from headache, or should he be delirious or convulsed—if his pulse becomes quick and hard, and his eyes are hurt by strong light—he has in all probability inflammation of the brain, which is the most frequent consequence of concussion, and must be at once met by the active depleting and reducing measures necessary for its cure, from whatever cause it may arise. In some cases the symptoms of concussion gradually change into those of compression, which may then be suspected to arise from effusion of blood into or on the brain, as in the cases already mentioned.

The account here given is only a sketch of the most prominent and constant symptoms, progress, and treatment of the effects of injuries of the head. There are other symptoms that occur occasionally, and as it were accidentally, which it is necessary briefly to advert to. Furious delirium, lasting for some days and requiring active depletion, sometimes immediately follows concussion; violent convulsions also ensue, either on slight compression or on concussion; paralysis or hemiplegia is not unfrequently produced directly by compression, and they still more commonly occur as its sequels. Loss of memory, sometimes most singularly limited to particular classes of events or things; impairment of individual sensations, and various forms of insanity, are all the occasional consequences of these injuries, or of the inflammation and disorganisation of the brain which follow them, and to the prevention or cure of which the chief attention is, in the majority of cases, to be directed.

HEADBOROUGH. [Constable.]

HEALTH. [Public Health.]

HEARING TRUMPET. [Ear-Trumpet; Speaking-Trumpet.]

HEARSAY. [Evidence.]

HEART, DISEASES OF THE. The heart, like the other viscera, is concealed from the eye, hence little knowledge of its healthy or diseased conditions can be obtained by mere inspection. Even the touch fails to ascertain much, on account of the bony case in which it is enclosed. Its impulse may, however, be detected by grasping the chest with the hand. The arterial pulse may be also felt by the finger, but these means of examination give but little information of the nature of diseases of the heart, compared with the use of the ear. Disease of the heart can be detected both by the aid of auscultation and percussion.

When the ear is applied to the left side of the chest, either directly or with the aid of the stethoscope, two sounds are heard, called the first and second sounds of the heart. [Heart, in Nat. Hist. Div.] The two sounds differ from each other, and the period of silence between the two sounds also differs. The first sound is longer than the second, and the two have been compared to the syllables *lupp* and *dupp*. It is heard most distinctly below and outside the left nipple, and with the systole of the ventricles, and on these accounts is called the *systolic* or *inferior* sound. The second sound is heard above and inside the left nipple, and is called the *superior* sound. It occurs with the diastole of the ventricles, and is called the diastolic sound.

The pause between these two sounds differs in the length of time it occupies: after the first sound and before the second it is *shorter* than between the second and the first.

These sounds present different characters in different individuals in health, and even in the same individuals at different times. They, however, indicate disease when they are permanently altered from their normal character. Thus they may be lower or higher, clearer or duller, muffled, rough, regular, irregular, intermittent, increased or decreased in number. Their quality may be altered, and they may be accompanied by friction sounds from disease of the pericardium, or murmurs may ensue from disease of the valves, as bellows, grating, filing, rasping, cooing, or whistling murmurs. There is also a relation between the sounds of the heart and the pulse. The first sound in health anticipates very shortly, but still very distinctly, the pulse at the wrist, hence any prolongation of this period is indicative of some obstruction to the course of the blood.

A knowledge of the nature and causes of the murmurs and abnormal sounds produced in the heart is essential to a correct diagnosis of diseases of the heart. These murmurs or morbid sounds may arise from disease within the heart, when they are called *endocardial*; or between the heart and its lining membrane, the pericardium, when they are called *exocardial*. The two classes of murmurs may co-exist. The endocardial murmurs arise either from an unnatural contraction or an unnatural widening of the orifices between the vessels and cavities of the heart. They may also arise from states of the blood. When caused by the latter they are called *functional* or *inorganic*, but when from the former *organic*. The exocardial murmurs arise from the roughening of the surfaces of the heart and pericardium.

Each of the orifices of the heart may be the seat of two different kinds of murmurs, the one constrictive, the other regurgitant; the one occurring *with* the current of the blood, the other *against* the current. In this way eight different kinds of murmurs are recognised. It should, however, be remembered that the murmurs on the left side more frequently occur than murmurs on the right side. The following account of these murmurs, given in the order of their frequency, will give an idea of their character and the means of distinguishing them.

1. *Mitral regurgitant murmur.*—This arises from inefficiency of the mitral valve by changes in its structure, roughness at its edges, from vegetatious shortening of the *chordæ tendineæ*, or fibrinious clots entangled in them. It is a systolic murmur, and is heard best immediately above or to the outside of the left apex. It is faintly or wholly inaudible at the right apex. It is generally permanent.

2. The *Aortic constrictive murmur* is the next most frequent abnormal sound in diseases of the heart. It indicates a rough constriction of the aortic orifice. It is a systolic murmur, and is heard best at mid-sternum opposite the interspace, between the third and fourth ribs, or the upper part of the fourth rib. It has a high pitch, and is a harsh, loud, and prolonged murmur.

3. *Aortic regurgitant murmur.*—It differs from the last in being heard almost as distinctly at the ensiform cartilage as at the third costal interspace. It is a diastolic murmur, and is of a blowing or hissing character.

4. *Mitral constrictive murmur.*—It is diastolic, and heard best immediately above and about the left apex.

5. *Tricuspid regurgitant murmur.*—It is due to regurgitation, or to the collision of the blood amongst the *chordæ tendineæ*. It is a systolic murmur, and is heard best immediately above or at the ensiform cartilage. It is inaudible, or nearly so, at the left apex. It originates in the right ventricle, and is generally a soft murmur of low pitch. It is a rare murmur, and may be often undiscovered when accompanied by a powerful mitral murmur.

6. *Pulmonary constrictive murmur.*—It indicates roughness, or obstruction from pressure in the pulmonary orifice. It is a systolic murmur, and is heard best at the sternal edge of the third left cartilage. It is rarely heard.

7. *Pulmonary regurgitant murmur.*—This indication of insufficiency of the pulmonary valves is very rare.

8. *Tricuspid constrictive murmur.*—It is the rarest of murmurs, is diastolic, and when heard is found at the ensiform cartilage.

The exocardial murmurs are produced by the rubbing of the surface of the pericardum against the heart, when these surfaces are roughened by the effusion of fibrine from inflammatory disease. They are more or less rough according to circumstances, and may entirely cease by the effusion of serum or fluid between the pericardium and the heart.

Percussion may be employed in distinguishing enlargement of the heart. It is employed either mediately or directly. [PERCUSSION.] In the normal condition of the thorax, the situation of the heart is easily distinguished by the dull sound given out on percussion. When this dull sound extends unnaturally in any direction over the region of the heart it is indicative of an enlargement of that organ, a condition which will be made evident by other signs of disease.

In giving some account of the disorders to which the heart is liable, it would perhaps be best to arrange them according to their causes; but as it is much easier to obtain a knowledge of the structure of this organ than of the remote causes of its several diseases, we shall here enumerate and describe, first, those lesions which occur in its investing membrane; secondly, those which affect it as a whole; and thirdly, those met with in its internal membranes. Those who desire to be further acquainted with this subject are referred to the works of MM. Corvisart, Laennec, Cruveilhier, Bouillaud, Bertin, and Drs. Elliotson, Hope, Watson, Latham, Taylor, Walshe, Williams, Billing, and Aitken.

I. *Diseases of the Investing Membrane of the Heart.*

Pericarditis, Inflammation of the Pericardium, resembles much, in its pathological conditions, inflammation of other serous membranes, and is induced by similar causes, as exposure to damp and cold. It of course presents peculiar symptoms, arising from the situation and nature of the individual organ: thus the patient will complain of tenderness over the region of the heart, amounting, when pressure is made, to acute lancinating pain, which prevents him from lying on the left side, and is much increased by drawing deep inspirations or coughing,—this latter symptom frequently depending on the pleura being involved in the inflammatory attack. This pain, however, is not always so severe; frequently only a sense of oppression is felt. The pulsations of the heart are frequent, sometimes regular, but at other times intermittent, and so strong as to constitute palpitations; but still, if much effusion has taken place into the pericardium, the hand when applied to the chest will have difficulty in perceiving them. The præcordial portion of the thorax is often bulged out by the forcible action of the heart and the quantity of fluid effused into the cavity of the pericardium. This effusion varies much in quantity and consistence at different periods of the disease: thus, in many cases, only a little bloody serum will be found; in others, pus in large quantities, coagulated lymph, bands of fibrinous matter uniting the two layers of the serous membrane, and even cartilaginous or osseous deposits. The dull sound discovered by percussion in the præcordial region of a person in health is always, in this disease, increased in proportion to the quantity of fluid in the pericardium. In proportion as this fluid becomes organised sounds will be heard by the application of the stethoscope, and often of the unassisted ear, varying in their nature according to the state of the organising process, and resembling at one time the creaking of new leather, at another the rubbing together of paper or parchment, the noise made by a file, &c. Other sounds also are frequently heard, which depend upon endocardial disease. Although at the commencement of the disease the patient may have symptoms of acute inflammation, the accompanying fever having a type sufficiently tonic, this state does not endure long; the effusions into the pericardium hinder the heart's action; the free passage of the blood through its cavities becomes further impeded by various internal parts of the organ sharing in the inflammation; and, the circulation being no longer vigorously and equally carried on, a crowd of distressing symptoms, such as inability to sleep, startings, faintness, shortness of breath amounting to suffocation, dropsies, &c., render life almost insupportable, and, if not speedily relieved, soon put an end to existence. This disease mostly accompanies acute rheumatism, particularly of the joints; and patients, when apparently recovering from acute rheumatism, are sometimes suddenly attacked and carried off by inflammation of the pericardium.

The serious nature of this disease, and the rapidity of its progress, demand, apparently, prompt antiphlogistic treatment; but, on the contrary, some physicians exhibit tonic medicines. Dr. Watson says, "In a large proportion of cases, whether they be treated well or ill, or not treated at all, the patients will seem to recover."

The great guide to treatment is the pressure of the symptoms. At the commencement of the disease, if there is dyspnœa and tumultuous action of the heart, bleeding will immediately relieve. Towards the termination of the disease such symptoms are relieved by wine and stimulants; otherwise the general treatment for rheumatism is admissible in cases of pericarditis.

II. *Diseases of the Heart itself.*

Carditis; Inflammation of the Heart.—The proper muscular structure of the heart is not free from the attacks of inflammation, though whether the morbid action commences in this structure, or in the membranes, is difficult to determine. This, however, is certain, that when inflammation of the muscular structure exists, there will also be found traces of it in the pericardium, or in the lining membrane of the heart, or in both; and we cannot point out symptoms which distinguish the one from those of the other disease: the treatment consequently, will be similar in both.

Hypertrophy of the Heart.—Independently of any morbid process existing in itself, the muscular structure of the heart is often greatly increased in bulk, as if the nutritive process were too active in proportion to the absorbent, and new matter were deposited more rapidly than the old could be removed. From the peculiar nature of the functions of the heart, this disease becomes very important, and its effects not less dangerous than manifold. It is usually divided into three kinds; namely, simple hypertrophy, the least common, in which the parietes are thickened without any change of capacity in the cavity; excentric or aneurismal hypertrophy, the form most frequently met with, in which the parietes are thickened and the inclosed cavity or cavities proportionally enlarged; and concentric hypertrophy, where the cavity is diminished in proportion to the thickness of the parietes. Any one of these kinds of hypertrophy may affect the parietes of either cavity of the heart, or of the whole organ. The extent to which this increase of size may proceed is enormous; hearts have been found weighing upwards of twenty ounces, whereas the average weight of a healthy heart is from seven to nine ounces. In hypertrophy, the shape of the heart is also much altered, the transverse often exceeding the vertical diameter; but these changes must depend upon whether the whole organ, or only a part, be implicated in the disease. The chest is often bulged out towards the left side, the sound produced by percussion more dull than in the healthy state, and the pulsations very strong; indeed, the bed-clothes are often visibly raised, and the head or hand of the observer when applied to the chest forcibly repulsed, yet the pulsations are for the most part regular, unless palpitations be induced by over-exertion. The sounds perceived by auscultation will be found very loud, but not otherwise unnatural, if the disease be not combined with some obstruction to the passage of the blood; and unless some obstruction exists, the functions of other organs will not be much deranged, provided that the hypertrophy be not of great extent; but it seldom does exist to considerable extent without the simultaneous occurrence of some impediment to the passage of the blood, already circulating with extraordinary force.

The accidents referrible to hypertrophy of the left ventricle of the heart are apoplexy and hæmorrhages; it will also contribute to the production of aneurism of the aorta. It frequently happens that the rupture of vessels in the brain by the too forcible expulsion of blood from an hypertrophied left ventricle is materially facilitated by an earthy or osseous state of the coats of those vessels. When the right ventricle, being hypertrophied, sends its blood too forcibly through the lungs, there will be a disposition to congestion of those organs. These effects will be combined when the whole heart is hypertrophied.

This is a disease in which great perseverance is required on the part of the patient and the practitioner, but with proper care it frequently admits of much alleviation. Rest, abstinence, sedative medicines, and more or less depletion, according to the circumstances of the case, are the most efficacious plan of treatment.

Atrophy of the Heart is a wasting of the heart's structure, dependent on deficiency of the nutritive process. This disease is the reverse of hypertrophy, and, like it, may affect the whole organ or only parts of it; its extent is often such that the heart does not exhibit more than half its ordinary weight. Like hypertrophy, it has been divided into simple atrophy, when the walls of one or more cavities are thinned without any change of capacity in the cavity itself; excentric or aneurismal atrophy, when the enlargement of the cavity keeps pace with the thinness of the walls; and concentric atrophy, where the cavity is diminished, but the walls maintain their usual thickness. This state of the heart is usually accompanied by general emaciation, and the pulsations and sounds of the organ will be found feeble in proportion to the extent of the atrophy. In concentric atrophy, however, the pulse will be firm and resistant, though small, whilst in the excentric form of the disease it will be proportionally soft, feeble, and large.

When the heart is examined after death from atrophy, it is found that its tissues have undergone a change which has been called "fatty degeneration." The muscular fibre, instead of presenting the striped character found in health, loses the stripes, and presents a homogeneous appearance. In the interior of the fibrillæ will be found also fat globules, and the central portion of the muscle-cells, consisting naturally of fibrine, is converted into adipocire or cholesterine. It is in this state of the heart that rupture of its membranes so frequently occurs. (Quain, 'Fatty Diseases of the Heart.')

In atrophy the powers of the patient are all below par, and the proper treatment will be to support the system by wholesome, generous, but unexciting diet, and a salubrious atmosphere. Medicines, as quinine and iron, may be prescribed as auxiliaries, when any additional symptoms appear indicating obstruction to the nutritive functions.

Dilatation of the Heart.—It has been shown that the heart may be increased or diminished in substance, or, in other words, may be hypertrophied or atrophied; it is also found that the whole organ, or either of its cavities singly, or the orifices of these cavities, may be dilated, the solid parietes being merely extended, without any increase of substance, and the contained cavities proportionally enlarged. As in hypertrophy, so in this disease, according to its extent, the shape of the heart will be much changed. The muscular parietes being thinned and feeble, the circulation of the blood will not be carried on with vigour, and the patient will be weak and unfit for exertion, easily exhausted by small losses of blood, and sometimes carried off by what under ordinary circumstances would be deemed a trifling hæmorrhage. Partial dilatations sometimes occur after carditis; the muscular structure being thinned at some spot by ulceration, the parietes give way, and form a dilated aneurismal pouch. This disease, though it doubtless does sometimes occur in persons of relaxed muscular fibre without any pre-existing impediment to the circulation, is most frequently the consequence of some obstruction to the free passage of the blood from the dilated cavity, and is the natural effect of distension from within. It however not unfrequently happens, that when the obstruction occurs at the orifice situated between the ventricle and artery the corresponding auricle will be the cavity dilated, its parietes being so much less strong than those of the ventricle. When the orifice of either of the cavities of the heart is dilated to such extent as to preclude its proper closure by the valves, a reflux of blood will be the result, causing the anormal bellows sound, and a sensation of purring, or of vibration such as would be produced by putting a chord in motion; and should this defective closure exist in the right auriculo-ventricular opening, it will give rise to a fluctuating motion in the jugular vein, called "venous pulse." Excessive exertions and strong passions seem to be exciting causes of this disease, and from the influence of these causes the patient should be sedulously guarded, and at the same time every remedy must be adopted which may contribute to equalise the circulation.

The preceding diseases are most frequently the result of disease of the lining membrane of the heart, and are often accompanied by the signs of valvular derangement.

III. *Diseases of the Internal Membranes.*

Endocarditis; Inflammation of the interior lining membrane of the Heart.—The symptoms of endocarditis are more or less fever and anxiety; some bulging of the præcordial region, if accompanied by pericarditis; an extension of the dull sound heard on percussion in the healthy state; the pulsations of the heart unusually strong, and sometimes very rapid and intermittent, repulsing the hand when applied to the chest, and producing a peculiar vibratory sensation. Upon auscultation the bellows sound will be heard, masking one or both of the normal sounds, and sometimes, during the ventricular contraction, a metallic tingling is heard, resembling the sound produced by dropping sand into a bell of metal. The pulse as felt at the wrist will not always accord with the beatings of the heart; often whilst the latter are very forcible, the former will be found small and weak, and sometimes less frequent: this indicates some obstruction to the free passage of the blood from the heart, notwithstanding the forcible contractions of that organ to propel it, and the patient will exhibit symptoms of much distress, as great anxiety of countenance, restless tossings of the body, dazzlings of the sight, and faintings; if the obstructions in the right side of the heart are extensive, as they often are from fibrinous concretions, thickenings, and other morbid growths of the valves, the venous circulation will be affected, as indicated by the livid bloated state of the countenance, and serous effusions into the extremities; various apoplectic symptoms seem to be sometimes induced by the same cause. The breathing is not affected generally beyond a sense of oppression, unless a considerable impediment is experienced by the circulation, but then the distress and restlessness of the sufferer is often extreme, accompanied by an inability to lie down, and a state of alarm and wandering amounting almost to delirium.

The causes of this serious malady are similar to the causes of pericarditis, and the treatment should be conducted on the same principles. It frequently arises in the course of an attack of rheumatism, and may or may not be accompanied by pericarditis.

Valvular disease of the Heart.—Upon examination after death from endocarditis, there will often be found, particularly in the right cavities of the heart, and entangled in the muscular fibres, clots or concretions of fibrinous matter, which are not only caused by stagnation of the blood at the time of death, but also by inflammation of the internal lining membrane. This membrane is also often thickened, especially at the valves; and after repeated attacks, or a long chronic attack of endocarditis, the valves will not merely be thickened, but will become the seat of a variety of warty excrescences, or even cartilaginous and osseous formations of considerable size, extending into the cavities of the heart. This ossification is most frequently met with in old persons, and especially those who have been addicted to a too generous mode of living. The morbid sounds produced by these obstructions at the various orifices will resemble those of the bellows, file, or saw, according to the degree of obstruction; and sometimes a triple or quadruple sound will be perceived instead of the two normal sounds. The effects of these obstructions will be sanguineous and serous congestions, oppressions of the breath, apoplectic seizures, and other symptoms of embarrassed circulation.

The treatment of such cases must depend on the nature of the symptoms present. Where anasarca is present, the water may be got rid of by rest and by acting on the bowels and kidneys. Asthma is frequently the result of valvular disease of the heart, and remedies must be applied to facilitate the passage of the blood through the obstructed lungs. Hæmorrhage from the lungs and extravasation of blood are produced by disease of the heart. Congestion of the brain and apoplexy are also the result of disease of the heart, and it is of the greatest consequence to detect the cause of these attacks in the state of the heart, and adopt treatment accordingly.

Nervous Diseases of the Heart.—The last class of diseases affecting the heart which remains to be noticed differs from all the preceding in not presenting any organic changes. They are met with chiefly in women suffering from anæmia, chlorosis, hysteria, and other nervous symptoms; and in men in whom a naturally nervous temperament has been rendered more irritable by the too free use of stimuli or by depressing passions. In these cases strong pulsations of the heart are experienced, increased by exertion to such an extent as to produce palpitations, a sense of faintness, and shortness of breath amounting to suffocation. Sometimes a loud bellows sound is heard at the heart, and in patients labouring under anæmia and chlorosis this is frequently accompanied by a noise like snoring, heard chiefly in the carotid and crural arteries. In all these cases great attention should be paid to the general health: in the cases of anæmia and hysteria, iron medicines and the shower-bath will be of the greatest service; and, as far as possible, sources of anxiety should be removed. The morbid sounds will all disappear as the mind and body of the patient are restored to their healthy condition, but it must be borne in mind that the heart is essentially a muscular organ, and by severe exercise it may be increased in bulk like other muscles; consequently if these nervous states which give rise to so much action of the heart be not removed, they may in process of time lay the foundation for more permanent and serious disease.

Malformation of the Heart.—Cases of permanent malformation of the heart are few. The only one demanding attention here is the permanent *foramen ovale.* [CYANOSIS.]

HEAT. This great natural agent, which is universally diffused, becomes sensible to us in the first instance by our bodily sensations, but we find afterwards its effects in the various changes which it is capable of producing on all substances. Expansion, fusion, evaporation, thermo-electric currents, and various physiological phenomena, are effects of heat, or at least accompany its absorption.

Every existing substance may be regarded as a source of heat. In this respect the sun is the most important natural source which our system possesses, its heat when condensed in the focus of a lens being exceedingly intense. When concentrated by a number of powerful lenses on one scale of a balance of extreme sensibility, no derangement of equilibrium ensues; as far therefore as experiment can inform us it is imponderable, and the increase or diminution of heat in any body is therefore unaccompanied by any alteration of weight.

Heat may be produced artificially by any means which propagate agitations internally in bodies: hence *friction*, *percussion*, sudden *condensation*, *chemical combination*, including *combustion* and *respiration*, and *electrical discharges*, are all proper to produce or rather to develope heat. Pouillet has also shown that the act of moistening any dry substance produces a rise in temperature of from ½° to 2° in dry mineral substances in powder, and from 2° to 10° or 11° in certain animal and vegetable substances, such as cotton, hair, wool, paper, &c.

As to the nature of heat, whether it should be regarded as a substance or an accident, has been discussed from the time of Bacon to the present day. Those who regard it as having a material existence, suppose that a subtle fluid, called *caloric*, capable of permeating the densest substances, is universally diffused; that its parts are mutually repulsive, but are attracted by the material particles of bodies, and hence they account for the expansions and contractions of bodies, while the effects of radiant heat are explained on principles analogous to those on which the undulatory theory of light is founded.

Those who regard heat as only accidental to matter, rest their opinion on the fact, that the artificial production of heat is accompanied by vibratory motions in the material molecules of the heated substances. The measure of the quantity of heat produced mechanically would on this hypothesis have a direct connection with the sum of the *vis viva* of the system of vibrating particles. Hence the communication of heat by contact would be the same as the propagation of vibratory motions from the system of particles composing the heated body to that of the touching body. This hypothesis is liable to a great objection; for heat is propagated through a vacuum, and if even we suppose all space filled with some fluid, in order to explain solar radiation, the hypothesis loses its simplicity, and differs from the former principally by its greater vagueness. It has been suggested by Brewster, that the solar rays are nothing more than heated light, but this opinion is open to several objections founded on the different laws by which heat and light are transmitted and modified.

It is of greater advantage to study the properties of heat, and make those properties the ground for its measurement and the calculation of its effects, than to speculate on the nature of an agent intimately connected, not only with light and electricity, but with the absolute nature of the material molecules.

Heat radiates from all bodies in straight lines and in all directions, and in the law of its emanation it resembles light, its intensity diminishing in the same proportion as the sine of the angle of emanation. If we conceive two balls which are heated unequally to be enclosed by a concave surface which by any means is preserved at a uniform temperature, the radiation of heat from the warmer ball, directed on the colder, being more copious than the radiation from the latter on the former, the temperature of the hotter will sink, and of the cooler rise, in proportion to the difference of radiations, and this will continue until the temperatures become permanent, in which case the radiations are necessarily equal. In the same manner, when the different parts of a room in which there are one or several sources of heat have acquired a permanent temperature, that temperature for each part will then be such that the heat which it emits by radiation must be equal to the quantity absorbed, and which it has received by radiation from all other parts of the room.

One consequence of the free radiation of heat in open space is, that its intensity must vary inversely as the square of the distance from the origin. Hence every portion of space has a determinate temperature due to the amount of radiation, not only from the sun and fixed stars, but also of the non-luminous bodies of each system. It seems however difficult to conceive with Poisson, that in addition to such temperature from heat emitted, it can have any temperature peculiar to its locality; in fact, that vacuum can possibly have any proper heat.

But though the laws of the free emanation of heat and light are similar, those of their transmission through substances are very different. When a metallic body is but a little heated in a fire, we have heat unaccompanied by sensible light; and in the lunar rays the light, though originally transmitted from the sun, arrives at our planet without any sensible heat, even when collected in the focus of a burning-glass. Again, a plate of glass placed before a common fire will intercept the heat until it becomes itself sufficiently heated to radiate. When however the source of heat is more intense, a small portion will be directly transmitted; while for the solar rays we find the heat is transmitted as well as the light. It is still more remarkable that when the solar rays are decomposed by transmission through a glass prism, the differently coloured rays of the spectrum have each a different intensity of heat, the least refrangible possessing the greatest portion; the greatest heat is found at the place occupied by the extreme red rays, or even a little beyond them.

Not only may radiant heat be collected in a focus by refraction through a lens, but also by reflexion from a polished concave mirror. If we employ a pair of mirrors, and if a heated body be placed in the focus of one, and a thermometer in the other, the reflected heat falling on the bulb of the instrument will cause the mercury to rise; and conversely, a colder body will make the column of mercury descend, for the excess of radiation proceeds in this case from the thermometer. Recent experiments on heat show that the analogy of the laws of heat and light extends even to polarisation.

The experiments of Leslie have shown how greatly the quantity of radiant heat may be affected by the state of surfaces from which it finally emanates. The method adopted by Leslie for examining the powers of radiation possessed by different substances was extremely simple and ingenious. Having employed the system of two specula above mentioned, he placed a tin canister filled with hot water in the focus of one, and a differential thermometer [THERMOMETER] in the other focus. The four sides of the tin canister were covered with the substances of which he proposed to seek the radiating powers; when three of the sides were respectively covered with lamp-black, paper, and crown-glass, and then turned so as to radiate directly on the speculum, the heat reflected by the other speculum raised the thermometer accordingly to 100°, 98°, and 90°; but when the fourth side, which was uncovered, was similarly directed, the thermometer fell 12°. Thus it appears that polished metallic substances are bad radiators, which may be attributed to the internal reflexion of the heat from their surfaces, for the sources of radiation must evidently be at some small depth below the geometrical surfaces. A similar apparatus served to measure the absorptive power of different substances, by covering the bulb of the thermometer as uniformly as possible with an envelope of the substance to be examined; this power was thus found to be nearly in proportion to that of radiation. The maximum effect of the reflected heat was not however in the strict geometric focus, but, in consequence of aberration, it was found to be a little beyond it. At a later period Ritchie contrived a species of differential thermometer from which, by direct experiment, he was enabled to prove that the power of radiation from any surface is exactly equal to that of absorption at the same surface. A hollow air-tight cylinder of tin, having one half of its exterior surface bright and the other covered with lamp-black, was fixed in a vertical position at each extremity of a bent glass tube containing a coloured spirit; and midway between these was placed a vessel similar to the others, and like them coated on half its surface. When the instrument was to be used, the middle vessel was filled with boiling water; then the bright side of one of the first-mentioned cylinders being turned towards the coated side of that which contained the water, while the coated side of the other was turned towards the bright side of the latter, the rarefaction of the air within the cylinders at the extremities of the tube, in consequence of the heat absorbed by them, was proved to be equal by the coloured spirit remaining stationary in the tube. ('Journal of the Royal Inst.,' December, 1831.) It is evident, here, that if the quantity of heat which radiated from the bright side of the middle cylinder were represented by $\frac{1}{n}$th of that which issued from the coated side; the bright side of the cylinder at one extremity of the tube absorbed $\frac{1}{n}$th of the latter quantity while the coated side of the cylinder at the other extremity absorbed all the former, that is, an equal quantity.

The power of radiating heat is certainly the most universal mode of its propagation between different particles of matter as well as through considerable spaces. However, it is usual, for greater simplicity, to designate this propagation through solid bodies as *propagation of heat by contact.* Poisson has shown in his memoirs on that subject, that the general equations which express the law of the distribution of heat in solids may be derived from the internal radiation of the particles which compose them. Whichever of these two views may be adopted, we are led to important physical distinctions between different homogeneous substances, viz. their conducting powers internally and externally. If we take two substances, as a piece of metal and of wood, at the same temperature as indicated by the thermometer, when held in the warm hand the metal will feel colder than the wood, the heat of the hand being more rapidly absorbed by the metal, as being the better *conductor* of heat. Or if we place the extremities of a rod of copper and of glass in a fire, and hold with the hands the other extremities, the heat will be found to ascend rapidly through the metal and very slowly through the glass rod. Though such plain observations are sufficient to give a general idea that bodies conduct heat differently, yet, to obtain exact measurements of conducting powers, it will be necessary to have a more precise idea, since such power is a constant coefficient belonging to every body in particular, and without the knowledge of which it would be impossible to compare the result of theory with observation.

Newton remarked that, when two substances of unequal temperatures were placed in contact, the colder received from the other in a given small time a quantity of heat proportional to the difference of their temperatures. This simple law has been found to be not strictly correct, but is sufficiently so when the difference of temperatures is inconsiderable. If t t' represent the temperatures of two bodies of the same physical nature placed in contact, and if we leave out of consideration the heat escaping by radiation from their surfaces, the quantity of heat communicated may, by Newton's law, be represented by $h\,(t-t')$; where the coefficient h is a constant peculiar to the given substance, and is proportional to the interior conductibility.

If now we conceive the surface of the body to be of a uniform temperature, and subject to a current of air also of a uniform but inferior temperature T, the loss of heat by a unit of surface in a unit of time indefinitely small will, by the same law, be represented by $H\,(t-T)$, where the coefficient H is proportional to the exterior conductibility under such circumstances.

The exterior conductibility may be very different in the same body by slight alterations in the smoothness or even colour of the surface; it is by this antagonist principle that heat acquires a permanent state corresponding to the different positions of the parts of bodies relative to the sources of heat and the dispersing surfaces.

The mathematical theory of the distribution of heat is founded on the principle that when a body has arrived at a permanent state of temperature the quantity of heat given out by any particle to the adjacent colder region must be equal to that received from the warmer particles near it, and conversely. For example, suppose a solid body to be contained by two parallel planes of indefinite extent, the lower plane being preserved by any means at a uniform temperature represented by 0, and the upper likewise preserved at a uniform temperature. In this case it is easily seen that the temperature would be uniform in any section of the body parallel to its bases, but would increase from the lower plane in an arithmetical progression to the upper, for with this law the temperature of any point of the body taken in the transverse direction will differ by equal quantities from the temperatures of any two points which are at equal distances, the one above and the other below it; hence the flux of heat from the warmer region to this point is equal to that from this point to the colder. Though there is therefore a constant flux of heat from the upper to the lower plane, the distribution of heat has then acquired a permanency.

In the above instance we have had no regard to the external conductibility through the sides by supposing the planes of indefinite extent. A simple instance will now be adduced in which we can show the manner in which this consideration may be introduced into the calculus.

Suppose a thin cylindrical rod to be placed in a medium of which the temperature is constantly zero, while its extremities are maintained at constant but different temperatures. In this case the distribution of heat will follow, at equal distances along the rod, a geometrical progression, increasing from the colder extremity to the hotter; for on this supposition the heat which would be retained by any section in consequence of the unequal differences of its temperature with those of sections similarly placed above and below it, if there were no radiation, will be exactly lost by the external means of conduction, for it is a property of the terms of a geometrical progression that the second differences are proportional to the terms themselves; the heat which would be retained is proportional to this second difference, and the heat externally emitted is proportional to the temperature itself. Thus this law, which renders the internal gain of heat equal to its loss externally, represents the law of its permanent distribution. Those who are acquainted with the calculus of partial differences may find these principles applied, not only to the permanent distribution of heat, but to the laws of cooling in bodies warmed from any sources, and bounded by any surfaces, in the excellent work of Fourier (*Théorie de Chaleur*), and in the memoirs of Poisson, Libri, and others.

The propagation of heat in liquids depends very little on any communication by contact. If we place a heated plate on the surface of water in a vessel, but so as not to touch the edges, a thermometer placed in the water will indicate little or no alteration of temperature; liquids are therefore heated by the transposition of their parts, or by *convection* as it is called. Thus, if with a blowpipe we apply heat to the bottom of a vessel containing water, in which are floating some small particles of dust, a current will be perceived of the warmed liquid rising from the point to which heat has been applied, and another descending current of the colder parts, which being heated in turn rise also; in this manner the heat is distributed through the whole liquid, for as the heat expands the particles of liquid which it first meets, they become specifically lighter than the adjacent fluid, and they must therefore ascend by the laws of hydrostatics, while the heavier take their places.

The experiments which have been made to determine whether liquids are conductors of heat, consist in introducing into a cylindrical vessel half filled with the fluid whose conducting power was to be examined, a quantity of heated fluid of less specific gravity, all due precautions being used to prevent the particles of the two fluids from intermixing; and it was constantly found that thermometers placed at different depths in the former indicated a gradual descent of caloric from the upper to the lower surface. By such experiments Thomson, Dalton, and others, have found that, with equal volumes of the fluids, the conducting power of linseed oil is rather greater than that of water, and the conducting power of mercury about twice as great.

Little as is the conducting power of liquids, that of gases is probably much less, if any; but there would be great difficulty in establishing this experimentally. The effect of heat on gases is to increase proportionally their elasticity, and this disturbing force produces violent motions in their parts, so that the whole shortly acquires a uniform temperature, when other forces, such as gravity, are not taken into consideration, and when the bounding surfaces are not essentially subjected to constant unequal temperatures.

These three modes of the propagation of heat exist in our globe, and are the cause of important phenomena in the distribution of climate.

First the great mass of the earth, considered in reference to its solid parts, has an external source of heat in radiation principally from the sun. The maximum quantity of this heat is bestowed on the region between the tropics, while the poles are at a temperature which, but for the action of the sea and atmosphere, would probably be that of space; the internal heat of the earth would in a homogeneous sphere be distributed symmetrically relative to its centre, diminishing towards the surface, which would lose heat by external radiation; but the external source of heat alluded to, by producing a flux from the equator to the poles, forms a permanent compensation for this radiation.

If we suppose the mass of the earth to have been at any remote period at a very high temperature, of which, besides its general form, there are many striking geological proofs, the effect of the radiation of its heat through the colder surrounding space would be to cool first the superficial strata, and successively, though in a less degree, the internal strata, until a permanent state was reached, when the diminished radiation would be exactly compensated from external sources. Hence, on descending below that comparatively shallow envelope affected with diurnal or annual variations of temperature, we ought to find a continually increasing temperature towards the centre, a result which has been verified in the mines in several countries in Europe. Poisson deems these experiments inconclusive, in consideration of the small depth which we are enabled to penetrate; for without assuming any increase of heat towards the centre, the same superficial phenomenon would occur on the supposition that the whole solar system had been transferred into a region of space possessing a different temperature from that in which it formerly moved; but this view, which is purely speculative, cannot be verified by facts.

The propagation of heat by motion in fluids has a necessary tendency to equalise the temperatures of different latitudes, and the unequal depths of different places in the bed of the sea would, from the same cause, produce currents warmer than the adjacent water. The elasticity acquired by portions of the air in contact with the warmer regions of the globe destroys the equilibrium of that fluid, and generates winds of which the heat is communicated to the districts traversed, while the counter-currents, or cold winds, rush forward to occupy the abandoned spaces. The earth having always had a rotation, a limiting surface necessarily existed beyond which the centrifugal force prevailed; hence if the surface of the earth has ever had a temperature of 212° Fahr., the waters now occupying the bed of the sea, being in a state of vapour, could have filled no more than the space between that limiting surface and the surface of the earth; but the greater cold would necessarily convert the vapour in the upper regions into water, which, descending in rain, would be again vaporised, and this reciprocal action going on during the process of cooling, would be capable of producing immense alterations on the earth's surface. It has been suggested by Mr. Babbage, that a cause of a similar nature may have led to the rings and belts of the superior planets.

Most of the instruments constructed to measure heat are founded on its general tendency to produce expansion, but a few of them on other properties of heat. Besides the various thermometers, we may notice the *calorimeter* of Lavoisier and Laplace, in which an internal chamber of a box is preserved at the temperature of melting ice, being constantly surrounded with that substance, guarded against the contact of the air: in a division of this chamber, a cell furnished with a stop-cock, a body is plunged at any temperature, and remains until it ceases to melt the ice, when the quantity of melted water conducted through the stop-cock is taken as a measure of the quantity of heat given out by the body. This instrument is of use in determining the *specific heats* of substances, and the calculation of *latent heat*. For the measurement of high temperatures, see PYROMETER.

The dilatation of substances by heat is, in general, nearly proportional to the increase of temperature, except when they are about to change their physical or chemical states; thus water near the freezing-point expands when the temperature is diminished, which is probably owing to the different arrangement assumed by its constituent particles preparatory to crystallisation.

The value of the thermometer mainly depends on the assumption that equal increments of heat produce equal amounts of expansion. Still, however, this is not strictly the case; mercury, for example, in the 10° between 30° and 40°, expands less than in the 10° between 200° and 210°, but it fortunately happens, that the increase in the capacity of the glass bulb, especially if the thermometer be made of crown-glass, very nearly compensates for the increasing rate of expansion in mercury. Between the freezing and boiling points of water, the thermometer may therefore be relied on; but above 212° the instrument is not so exact. In general, in all bodies, there is an increasing rate of expansion for increasing temperatures. In the case of mercury, Regnault found that between 32° and 212°, its expansion was 1 in 55·08; between 212° and 392°, making an equal interval, it was 1 in 54·61, and between 392° and 572°, also an equal interval, it was 1 in 54·01. Platinum expands more equably than any other of the metals; but gives a similar increase in the rate of expansion as the temperature rises. According to Dulong and Petit the increase in dilatation of the following substances is the result of experiment:—

Materials employed.	Between 32° and 212°.	Between 32° and 292°.	Between 32° and 572°.
Glass	1 in 69660	1 in 65340	1 in 59220
Platinum	1 in 67860		1 in 65340
Iron	1 in 50760		1 in 40860
Copper	1 in 34920		1 in 31860
Mercury	1 in 9990	1 in 9665	1 in 9518
" (Regnault) . .	1 in 9915·7	1 in 9776	1 in 9647·6
" in glass . .	1 in 11664	1 in 11480	1 in 11372

Regnault further found that the dilatation of mercury between 32° and 662° was 1 in 9582·7. At high temperatures air is more reliable than mercury. The temperature of 572°, as measured by an air-thermometer would, if measured by a mercurial thermometer be 586°. In gases, and also in vapours considerably above their points of condensation, the expansion is the same in all under similar variations of air and pressure, and in general it may be stated that from the freezing to the boiling point of water they increase in bulk more than one-third, 1000 parts at 32° becoming 1366 at 212°. Rigid inquiry, however, by such observers as Regnault and Magnus, show that the co-efficient of expansion is not strictly uniform for all aëriform bodies: the expansion is greater for those which are most readily condensable, but most uniform for gases which have not been liquefied. Practically, however, there is but little chance of error in the statement that gases and vapours between 32° and 212° expand by heat $\frac{11}{30}$ths of the volume at 32°, or about $\frac{1}{409}$ for each degree of Fahrenheit.

It was noticed by Mitscherlich that doubly refracting crystals under the influence of heat expand unequally in different directions. A crystal of calcareous spar, for example, when raised from 32° to 212°, elongates most in the direction of the optic axis, and contracts in directions at right angles to this. As in the case of liquids, solids expand unequally for equal additions of heat; zinc expanding much more than iron, and iron more than glass. The total expansion of a body may be obtained very nearly by multiplying the linear expansion by 3. The following table gives the expansion in length and in bulk of certain solids between 32° and 212°:—

1·000,000 Parts at 32° Fahr.	Become at 212° Fahr.	EXPANSIONS.		Authorities.
		In Length.	In Bulk.	
English flint-glass .	1·000,811	1 in 1248	1 in 416	Lavoisier and Laplace.
Glass tube (French)	1·000,861	1 in 1148	1 in 382	Dulong and Petit.
Platinum . .	1·000,884	1 in 1131	1 in 377	
Palladium . .	1·001,000	1 in 1000	1 in 333	Wollaston.
Tempered steel .	1·001,079	1 in 926	1 in 309	Lavoisier and Laplace.
Antimony . . .	1·001,083	1 in 923	1 in 307	Smeaton.
Iron . . .	1·001,182	1 in 846	1 in 282	Dulong and Petit.
Bismuth . . .	1·001,392	1 in 718	1 in 239	Smeaton.
Gold . . .	1·001,466	1 in 682	1 in 227	Lavoisier and Laplace.
Copper . . .	1·001,718	1 in 582	1 in 194	
Brass . . .	1·001,866	1 in 536	1 in 179	
. . .	1·001,909	1 in 524	1 in 175	
. .	1·001,937	1 in 516	1 in 172	
Lead . . .	1·002,848	1 in 351	1 in 117	
Zinc . . .	1·002,942	1 in 340	1 in 113	Smeaton.

EXPANSION OF LIQUIDS.

At 32° Fahr.	At 212° F.	Expansions.	Authorities.
1,000,000 parts of mercury become	1,018,153	1 in 55	Regnault.
" " water "	1,046,600	1 in 21·3	Dalton.
" " oil "	1,080,000	1 in 12·5	
" " alcohol "	1,111,000	1 in 9	

It will be seen from this last table, that liquids expand much more rapidly than solids, and differ in that property to a much greater extent, the most volatile being the most expansible.

The amount of force exerted by the expanding or contracting of a body under varying changes of temperature is equal to that which would be required to elongate or compress it to the same extent by mechanical means. According to Barlow, a bar of malleable iron, 1 square inch in section, is stretched $\frac{1}{10,000}$th of its length by 1 ton weight; a similar elongation is produced by a rise in temperature equal to about 16° Fahr. The difference between the summer and winter temperatures in this climate is sufficient to cause an iron bar, fastened by its extremities to exert a strain of many tons on the square inch. In engineering and other works it is necessary to make some provision for expansion and contraction. Instances of it are familiar in the cracking of glass and cast iron: the sudden application of heat produces a sudden dilatation on the surface, which is torn away as it were from the interior and colder portions. The unequal contraction due to sudden cooling may produce a similar effect. In the application of solders and cements, regard must be had to the relative expansions of the solders and the bodies soldered. Iron, platinum, and glass do not greatly differ in their rates of expansibility, and hence those two metals may be soldered into glass, whereas silver, gold, copper, and some other metals differ greatly in their rates of expansion from glass, so that when soldered into it, they separate as the joint cools.

Reference has been already made to the three methods concerned in the equilibrium of temperature. But we may be allowed in this place to state a few of the results of modern scientific enquiry on those important processes.

And first, as to conduction. Several distinct sets of investigations have been made as to the relative conducting power of different solids. Wiedemann and Franz ('Pogg. Annal.' lxxxix.) employed equal bars of the substances, and exposed one extremity of each to a uniform source of heat: the progress of the temperature along each bar was measured at intervals of 2 inches by means of a thermo-electric arrangement. Their conclusion was, that the conducting power of metals for heat proceeds in the same order as their electrical conducting power. Calvert and Johnson ('Phil. Trans.,' 1858) employed two vessels of vulcanised India rubber on account of its low conducting power, and passed in succession bars of metal (each 2·36 inches long, and 0·393 inch square), through an opening in one of the sides of each vessel, into which it projected one-sixth of its length, the portion outside and between the two vessels being covered with vulcanised India rubber. A given weight of cold water, sufficient to cover the bar, was poured into one of the vessels and the temperature carefully noted, while into the other vessel was poured a given weight of water at 194°, that temperature being maintained for 15 minutes by the occasional injection of steam. The temperature of the colder vessel was then taken, and a comparison of its rise in temperature when bars of different metals were employed, gave the relative conducting power, correction being made for the loss of heat by radiation and transfer from one vessel to the other. The following table, based on these experiments, represents rather the order of conductability than the conducting power of the metals, for in order to obtain this, it would be necessary to repeat the experiments with bars of the same metals of different lengths:—

Metals Employed.	Rise in Temp. Centigrade Scale.	Mean Conductability. Silver = 1000.
Silver	31·90	1000
Gold	31·30	981
Gold alloy $\frac{991}{1000}$ . . .	26·80	840
Rolled copper	26·95	845
Cast copper	25·87	811
Mercury	21·60	677
Aluminum	21·20	665
Rolled zinc	20·45	641
Cadmium	18·40	577
Bar iron	13·92	436
Tin	13·45	422
Steel	12·65	397
Platinum	12·15	380
Sodium	11·65	365
Cast iron	11·45	359
Lead	9·17	287
Antimony	6·85	215
Bismuth	1·95	61

Of the metals employed in obtaining the above results the platinum, aluminum, iron and sodium were commercial samples: the other metals are supposed to have been chemically pure, and this is a point of great importance since the presence of small quantities of alloy greatly impairs the conducting power. The presence of carbon in iron, exerts a similar effect. Taking silver at 1000, and bar iron at 436, steel was found to be 397, and cast iron 359. Mercury in the above table is stated too high; the result being probably influenced by convective currents which were not counteracted.

It has been shown by De Senarmont ('Ann. de Chimie,' 3, Serie xxi. xxii.) that the conducting power of homogeneous solids, and of crystals which belong to the regular system, is uniform in every direction, yet in crystals which do not belong to a regular system the conducting power varies in different directions with respect to the optic axis. For example, if a slice of quartz be cut parallel to the axis of the prism, and another slice cut at right angles to that axis, and a silver wire be passed through the centre of each plate so that the other ends may be heated in a flame, a film of bees' wax smeared over each section will be melted differently when the wire is heated. In the plate cut across the axis, the wax will be melted in the form of a circle with the wire in the centre; while on the other plate the wax will be melted in the form of an ellipse, the long axis of which coincides with the optic axis of the crystal, thereby showing the superior conducting power in this direction than in the one at right angles to it. De la Rive and De Candolle long since showed that wood conducts heat much better with the grain than across it, and Tyndall ('Phil. Trans.' 1853) has proved that heat passes rather more rapidly in a direction from the external surface towards the centre than in a direction parallel with the ligneous rings, the greatest conducting power coinciding with the direction of greatest porosity and readiest cleavage.

Heat is reflected from different substances very unequally. The reflective power is greatest in polished metals, but they differ greatly among themselves. Out of 100 rays, according to Melloni, silver reflects 90, bright lead 60, and glass only 10: the remainder are absorbed. It has been estimated that the sun's rays, in traversing a column of air=6000 feet high, lose one-fifth of their heat by absorption. But Melloni was the first to make known the remarkable fact that the amount of heat absorbed by the same body varies with the source of the heat, with the exception of lamp black, which appears to absorb all the rays which fall upon it from whatever source. Melloni used as sources of heat the naked flame of an oil lamp, a platinum wire heated to redness in the flame of a spirit lamp, a sheet of copper heated to between 700° and 800° in a current of hot air rising from a lamp beneath it; and a copper canister filled with boiling water. The ball of the thermoscope covered with lamp black, may evidently be placed at such a distance from each of these sources of heat that the liquid shall stand in each case at the same point, so as to indicate the same temperature. Noting these distances and covering the ball of the thermoscope with another substance instead of lamp black, the instrument will apparently receive different proportions of heat, although placed at the distances at which when coated with lamp black the heat appeared to be equal. For example, if the absorption of lamp black from each source of heat be=100, the thermoscope coated with white lead at the same distance from the naked flame as before indicated only 53. The following table will show the variations in this respect, or the relative absorbabilities of different kinds of heat.

Absorbing Surface.	Naked Flame.	Incandescent Platinum.	Copper at 750° F.	Copper at 212° F.
Lamp black	100	100	100	100
White lead	53	56	89	100
Isinglass	52	54	84	91
Indian ink	96	95	87	85
Shell lac	43	47	70	72
Polished metal	14	13·5	13	13

Melloni also discovered remarkable differences in the power of certain bodies to transmit heat through them. Those which were transparent to heat he termed *diathermanous* or *diathermic* (from δια through and θερμος hot) while those which do not allow heat to pass are termed *athermanous* or *adiathermic*. Bodies that are transparent to light are by no means equally so to radiant heat. There is only one known solid that approaches to perfect diathermacy, and that is rock salt. Colourless gases are diathermanous in the highest degree; but all liquids hitherto examined have considerable absorptive action on the thermic rays. A fuller notice of this subject will, however, be given under RADIATION. For other important divisions of our subject we refer to LATENT HEAT; SPECIFIC HEAT; STEAM; DEW; EVAPORATION; BOILING OF LIQUIDS; EBULLITION; FREEZING; CRYOPHORUS; and some other kindred subjects.

Respecting the chemical agency of heat we give no details, seeing that no chemical operation can be performed without some disturbance of temperature or some alteration in the latent and specific heats of bodies. We cannot dissolve any salt in water without a disturbance of temperature, or combine or decompose substances, without similar and often very energetic manifestations of heat.

We must however just refer to what is called the mechanical theory of heat, which has of late years excited revived attention in consequence of the experiments of Joule ('Phil. Trans,' 1850) on the definite amount of heat developed by friction. The mathematical theory of heat started by Carnot was favourable to Joule's result, and has been revived by Clausius, Rankine, W. Thomson, and others. The reader interested in the subject will find an excellent resumé of the theory of the mechanical action of heat or thermo-dynamics by Professor Rankine in Nichol's 'Cyclopædia of the Physical Sciences.' The principle sought to be established by this theory is as follows:—that in all cases where mechanical effect is produced by heat, a quantity of heat is used up proportional to the mechanical effect produced; and conversely that the same quantity of heat can be again generated by the expenditure of just so much mechanical effect. Thus it appears from Joule's experiments that the actual quantity of heat developed by friction, depends simply on the amount of force expended, and not on the nature of the substances rubbed together. When water, for example, is agitated by means of a horizontal brass paddle-wheel, made to revolve by the descent of a known weight, the temperature of one pound of water is raised one degree Fahr., by the expenditure of an amount of force, sufficient to raise 772 lbs. to the height of one foot. So also when cast iron is rubbed against iron, the force required to raise 1 lb. of water 1° Fahr. is about 775 lbs., and by the agitation of mercury with an iron paddle wheel 774 lbs. These results are the means of a large number of experiments, and the conclusion drawn from them is, that the quantity of heat, capable of raising the temperature of 1 lb. of water (between 55° and 60°) by 1° Fahr., requires for its evolution the expenditure of a mechanical force, equal to the raising of 772 lbs. one foot. This is the mechanical equivalent of a unit of heat, and is known as Joule's equivalent. Expressed in terms of the French metrical system the heat capable of raising one gramme of water 1° C. is equivalent to a force which would lift 423·55 grammes through a height of 1 metre. But not only heat and motive power, but all other kinds of physical energy, such as chemical action, electricity, and magnetism, can be experimentally proved to be convertible and equivalent; that is, any one of these kinds of force may by its expenditure be made the means of developing any other in certain definite proportions.

There are certain reservations to be made in using such words as *heat* and *temperature*, but our remarks on this subject had better be deferred until we come to speak of the method of graduating thermometers. See THERMOMETER.

HEBREW LANGUAGE forms a branch of that extensive family of languages known by the name of Semitic; a name which is derived from the real or supposed descent of the people who speak these languages from Shem the son of Noah. The Semitic languages may be divided into three branches: the Arabic, to which the Ethiopic is closely allied; the Aramæan, consisting of two dialects—the Babylonian or East Aramæan (sometimes but erroneously called Chaldee), and the Syriac or West Aramæan; and the Hebrew, to which the Phœnician and Punic are closely related. Of these languages the Arabic is the most copious, and the Aramæan the poorest and least developed; the Hebrew holds an intermediate rank between these, being more perfect than the Aramæan, and inferior to the Arabic.

The Hebrew language derived its name from the Hebrews, who date their origin from Abraham, who is called 'the Hebrew' (הָעִבְרִי) in Gen. xiv. 13. The etymology of this word is doubtful. According to the Jews it is derived from Eber (עֵבֶר), an ancestor of Abraham (Gen. x. 24, 25; xi. 15); but Gesenius and many other critics maintain that Eber cannot be regarded as a historical person, and that his name has been invented in the same manner as the names of Ion, Dorus, Æolus, &c, by the Greeks, to account for the origin of the people. It has been supposed with some probability that the name of 'Hebrew' was originally applied to designate all the Semitic nations west of the Euphrates, which appear to have emigrated from Mesopotamia. According to this etymology, the word 'Hebrew' is derived from the root עָבַר, 'to pass over.' This appears to have been the opinion of the translators of the Septuagint, who render Gen. xiv. 13, 'Abram the Hebrew,' by Ἄβραμ τῷ περάτῃ, that is, 'Abram the passer-over.' All the descendants of Abraham were, according to this view, originally called Hebrews; and the name was only restricted afterwards to the inhabitants of Palestine. (See Ewald, 'Hebrew Grammar,' § 3; and Gesenius, 'Hebrew Lexicon,' under עִבְרִי.) This name is never applied to the language of the Hebrews in the Old Testament; in Isaiah xix. 18, it is called the language of Canaan (שְׂפַת כְּנַעַן); and in Isaiah xxxvi. 11, 2 Kings xviii. 26, 2 Chron. xxxii. 18, and Neh. xiii. 24, the Judaic or Jewish language (יְהוּדִית). The language spoken in Palestine in the time of Christ is frequently called Hebrew (Ἑβραϊστί) in the New Testament (John v. 2; xix. 13; Acts xxi. 40; xxii. 2; xxvi. 14); by which the Aramæan is probably intended. In the writings of the Rabbinical Jews the Hebrew is generally called the 'holy language' (לְשָׁן הַקֹּדְשָׁא).

The Hebrew language appears to have been formed in Palestine by a union of the ancient Aramæan, which was brought by the Abrahamites from Mesopotamia, with the Phœnician or Canaanitish, the language of the original inhabitants of the country. That the Phœnician and Hebrew languages were very closely allied is evident from the Phœnician names of persons and places, and from the specimens of the Phœnician language which we possess in coins and inscriptions. (Bochart, 'Geographia Sacra,' b. ii. cc. 1–7; Bellermann, 'Handbuch der Bibl. Lit.,' vol. i. sect. 56; Bellermann, 'Versuch einer erklärung

der punischen Stellen im Pönulus des Plautus;' Dessen, 'De Phœnicum et Pœnorum inscriptionibus,' Berl. 1810; Dessen, 'Bemerk. über phönizische und punische Münzen;' Gesenius in an Excursus entitled 'Über die phöniz. und punische Sprache und ihr Verhältniss zur hebräischen,' in his 'Geschichte der Hebr. Sprache;' Gesenius, 'Versuch über die malthesische Sprache,' 8vo, Leip. 1810; 'Paläographische Studien, über phöniz. und punische Schrift,' 4to, Leip. 1835; E. Rénan, 'Histoire Générale des Langues Semitiques,' Paris, 1855; M. A. Levy, 'Phönizische Studien,' chiefly relating to Phœnician inscriptions on gems, seals, &c., Breslau, 1858.) The long settlement of the Hebrews in Egypt, and their forty years' wandering in the wilderness, must have had an important influence upon their language; but the number of Egyptian words received into it appears to have been small.

Many critics have divided the history of the language into four periods:—I. From Abraham to Moses. II. From Moses to Solomon. III. From Solomon to the Babylonish captivity. IV. From the Babylonish captivity to its final extinction as a spoken language. But there are in reality only two periods in which any difference can be traced in the language; the first extending from the time of Moses to the reign of Hezekiah, and the second from the reign of Hezekiah to its final extinction as a spoken language. The language in which the Pentateuch is written differs so little from that of David, Solomon, and Isaiah, who lived many centuries after the time of Moses, that many critics, supposing it impossible that a language should have remained stationary for so many centuries, have maintained that none of the books of the Old Testament were written previous to the time of David and Solomon. It is not very easy to disprove this opinion; but the remarks of Ewald on this subject appear worthy of attention. He observes in his 'Hebrew Grammar,' § 7 (Eng. trans.), that "the Hebrew language in the first four books of the Pentateuch, which contain records of unquestionable antiquity, partly by Moses or from his time, appears already, a few minutiæ excepted, fully developed.

"From Moses until about the year 700 it underwent two changes; for as the structure of the Semitic language is in general more simple, so also is it less changeable than that of languages of greater development, as Sanskrit; to which is to be added, that in that period the Hebrews did not experience those influences which materially affect a language; they did not advance much in civilisation, were never long subjected to nations of foreign tongue, and lived almost entirely separated from all nations, especially from nations of foreign language. Their language, therefore, advanced little in development, but it also suffered little from corruption. There are, however, in those books of the Pentateuch some certainly important differences which afterwards disappear, and many differences of that kind have become less distinguishable by us, because the more modern punctuation has treated all words according to one standard, and that the standard of the language at a late period." The study of the Hebrew language appears to have been greatly promoted by the schools of the prophets, which were founded by Samuel; and it is to the influence of these schools that we are probably indebted for the lyric poems of David and the didactic and amatory poetry of Solomon.

The conquests of the Assyrians and Chaldæans from about B.C. 720 tended to introduce the Aramæan language into Palestine. It appears from Isaiah (xxxvi. 12) that the principal people in Judæa, even in the reign of Hezekiah, found it necessary to study Aramæan. The Aramæan colonies (2 Kings, xvii. 24), which were planted in the kingdom of Israel to supply the place of the Israelites who had been carried into Assyria by Shalmaneser, must have caused the spread of the Aramæan language in the northern parts of Palestine even before the destruction of the kingdom of Judah. The long residence of the Jews in Babylon after the destruction of Jerusalem by Nebuchadnezzar, caused the extinction of the Hebrew as a spoken language, at least among the common people. After their return to Judæa, according to the edict of Cyrus, it appears from a passage in Nehemiah (viii. 8), that the common people did not understand the Scriptures when read to them in the Hebrew language. But Hebrew continued to be spoken by the upper classes for a considerable time after the Babylonish captivity. The prophecies of Haggai, Zechariah, and Malachi, who lived in the latter part of the 6th century, are written in tolerably pure Hebrew. The inscriptions of the coins of the Maccabees are in Hebrew; and the Hebrew language does not appear to have been discontinued in writing and conversation among the upper classes till the century preceding the birth of Christ.

But the Hebrew, from the period of its extinction as a spoken language, has been always more or less cultivated by the Jews. After the destruction of Jerusalem by the Romans, numerous schools were established by the Jews, in which their language and literature were taught. Of these schools the most celebrated were those of Tiberias and Babylon. The Mishna, which contains the traditions of the Jews and interpretations of the Scriptures, is supposed to have been compiled in the latter part of the 2nd or the beginning of the 3rd century, by Rabbi Jehuda. The Mishna was considered from this period one of the principal works of Hebrew literature, and the rabbis of Tiberias and Babylon wrote numerous commentaries upon it. These commentaries were at length collected into two separate works, and entitled the Jerusalem and Babylonian Talmuds. The Jerusalem Talmud appears to have been compiled in the 3rd or 5th century, by Rabbi Jochonan; and the Babylonian Talmud in the 6th century, by Rabbi Asci. Each Talmud is divided into two parts: the Mishna, or text; and the Gemara, or commentary. The 'Mishna' has been edited by Surenhusius, 6 vols. fol., Amst., 1698. The Babylonian Talmud was published at Berlin and Frankfort, 12 vols. fol., 1715; and the Jerusalem Talmud at Amsterdam, fol., 1710. To the same schools we are also indebted for the system of punctuation and accents which we have in the Hebrew Bible. This system, which no doubt represents faithfully the traditional interpretation of the Scriptures and pronunciation of the language by the Jews, is entitled Masora (מְסוֹרָה), that is, "tradition." It is uncertain how long the school of Tiberias lasted; but the Babylonish school was broken up by the Arabs A.D. 1040, after a long period of prosperity, and most of the scholars took refuge in Spain, where they founded schools in most of the principal cities. These schools produced a succession of writers, of whom the most celebrated was Maimonides [MAIMONIDES, in BIOG. DIV.], who lived at the latter end of the 12th century. After remaining in Spain for nearly four centuries, they were banished by the Christians in 1492.

The Christians paid very little attention to the Hebrew language before the Reformation. The publications of the Buxtorfs in the 17th century tended to diffuse the language among Christians, but their works contained no philosophical views of the language, since they implicitly followed the decisions of the Masorites. The Grammar of Schultens, which appeared in 1731, and which may still be consulted with great advantage by Hebrew scholars, contained a much clearer development of the principles of the language than the Buxtorfs had given. His knowledge of Arabic enabled him to compare the forms of that language with the Hebrew, and thus to draw the attention of scholars to the important fact, that the study of the cognate languages is necessary to obtain an accurate knowledge of Hebrew. But the publications of Gesenius and Ewald, in the present century, have done more to facilitate the acquisition of the language than the works of all preceding writers.

It appears probable that the language of a country, which was divided both physically and politically into several parts, must have contained various dialects; but this cannot easily be proved, since almost all the Hebrew writers belonged to the kingdom of Judah. The language of Galilee and the northern parts of Palestine appears at all times to have inclined to the Aramæan; in the time of Christ, the Galilæan dialect differed from the language spoken in Judæa. (Matt. xxvi. 73.) In the book of Judges (xii. 6), the pronunciation of the Ephraimites is distinguished; and many critics think that they can discover traces of the northern dialect in the song of Deborah. (Judges, v.)

Few literary subjects have occasioned greater discussion than the letters, vowels, points, and accents of the Hebrew language. But with regard to the letters it appears probable, that the present square characters in which Hebrew is written were not employed previous to the Babylonish captivity, but that the Phœnician letters were used, which are still preserved with a slight alteration in the Samaritan alphabet. According to the Jewish tradition, the present square characters, which belong to the East Aramæan language, were first introduced by Ezra when he revised the canon of Scripture; but they could not have been universally adopted till a later period, since the Samaritan Pentateuch, which was not introduced into Samaria till after the Babylonish captivity, was written in the ancient character, and the coins of the Asmonæans in the 2nd century before Christ also employ the same character. It is difficult to say when the change was introduced. It has been conjectured that the square characters were in use in the time of Christ, from his referring to the letter *yod* as the smallest letter in the alphabet; a fact which is true of the present Hebrew alphabet, but would not apply to the ancient Hebrew or Phœnician alphabet.

It is a characteristic of the Hebrew language, according to the system of most modern Hebrew grammars, that the alphabet consists only of consonants, and that the vowels are expressed by means of small points placed above and below the letters. The antiquity of these points has occasioned great controversy among the learned. Some have maintained that the points are as ancient as the letters, and that both the points and letters were taught Moses by God himself; others, that the points were first introduced by Ezra when he transcribed the Scriptures in the present square characters; others, that the Hebrews had originally three vowel points, *a*, *i*, and *o*, answering to the three letters א י, ע, and that the present system of punctuation was not introduced till the time of the Masorites; but it is now generally considered by eminent Hebrew scholars, Gesenius, Winer, Ewald, &c., that the whole system of punctuation was first introduced by the Masorites, of whom some account has been given above, perhaps as early as the 6th or 7th century, and certainly not later than the 10th or 11th. It appears certain from many circumstances that the Hebrew letters were originally written without points. They are not found in ancient Jewish coins and inscriptions; they are not once mentioned or alluded to in the Talmud; they appear to have been unknown to Origen and Jerome; the ancient versions, such as the Chaldee paraphrases of Jonathan and Onkelos, and the Greek translations of Aquila, Symmachus, Theodotion, and the Septuagint, must have been made from Hebrew manuscripts without points, since they frequently give a different interpretation to the words from that which they must mean according to the present system of punctuation; and it is allowed that all the other Semitic languages had anciently no points. The best arguments on both sides of the question are given in Buxtorf's 'Tiberias, sive Commentarius Masorethicus,' 4to, 1620, in which the antiquity of the points is maintained, and in Capellus's 'Arcanum Punctationis revelatum,' 4to, 1624, in which their antiquity is denied. Further information on the subject will be found in most grammars. The system of accentuation depends on that of points, and was in all probability introduced at the same time. The accents mark the relation of one word to another in a sentence, and thus serve an important purpose in the syntax of the language. Many scholars have considered the accents almost useless; but one of the most eminent Hebraists of the present day remarks (Ewald, 'Hebrew Grammar,' § 642, Engl. Transl.), "We everywhere find a beautiful harmony between the accentuation and the syntax, so that they mutually support and explain each other. Whether we set out from the syntax, and learn to comprehend it without knowing any thing of the accentuation, or whether we proceed from the accentuation to the syntax, an accurate investigation will always lead to the same results, so that he who thoroughly understands the syntax is for the most part clearly possessed of the accentuation also, and he who understands the latter becomes throughout more easily at home in the former. This is, however, at the same time the best commendation of the accentuation." We must distinguish, however, the accentuation of the historical and poetical books. The remarks of Ewald apply only to the accentuation of the historical books. Many of the accents in the poetical books serve the same purpose as those in the historical; but the greater part were intended to indicate the tone according to which the Scriptures were chanted in the synagogue. The accents are explained with great clearness in Stuart's 'Hebrew Grammar.'

HEBREWS, EPISTLE TO THE, a book of the New Testament. The absence of the initiatory formula usual in the apostolic epistles has led some to doubt whether this book is an epistle or a dissertation. But it contains allusions to particular circumstances, which prove it to be an epistle (v. 11, 12; vi. 9, 10; x. 32-34; xiii. 19, 22, 23). The general opinion respecting the persons to whom this Epistle was addressed is that they were the Jewish converts in Jerusalem or Palestine generally. This opinion, as Michaelis has shown, is supported by the contents of the book itself. (Marsh's 'Michaelis,' vol. iv. pp. 193-7.) Others suppose it to have been addressed to the Jews of Asia Minor, and Dr. Noesselt contends for its having been written to the Thessalonians. Concerning the language in which this epistle was written critics have been much divided; some supposing that it was written in Greek, and others that it was written in Hebrew and translated into Greek. The latter opinion was held by Clement of Alexandria (who states "that it was written by Paul in the Hebrew language for the use of the Hebrews, and that Luke translated it for the benefit of the Greeks"); by Eusebius, and by other fathers; and is strongly advocated by Michaelis. The other opinion is supported by Lardner, Macknight, Rosenmüller, Professor Stuart, and most modern commentators.

The author of this Epistle is equally uncertain. The general voice of tradition assigns it to the apostle Paul, but it has also been ascribed to Barnabas, to Luke, to Silas, and to Apollos.

In the first ages of the church it appears to have been generally considered as a production of the apostle Paul, though great doubts were very early entertained on the subject. In the Alexandrian church we have the testimony of Pantænus (A.D. 180) to its Pauline origin, as well as that of Clement, in the passage quoted above, and in other parts of his writings. These testimonies are preserved by Eusebius ('Hist. Eccles.,' book vi. c. 14). Eusebius also quotes a passage from Origen (*Ibid.*, c. 25), which has been variously understood, but which seems to imply that an objection had been raised against the Pauline origin of the epistle from the superiority of its style to that of the acknowledged Epistles of Paul, and that to meet this objection Origen supposed the sentiments to be Paul's, but the diction that of some other person, a disciple of Paul. But he adds: "If any church therefore hold this epistle to be Paul's, let it receive commendation for this. For it is not without reason that the ancients have handed it down as Paul's." In Origen's own writings it is frequently quoted as being written by Paul; and after his time the Alexandrian fathers unanimously ascribe it to the same apostle. Turning to the Eastern church we find passages in the writings of the fathers, which are thought by some to be indirect quotations from this epistle. The earliest direct testimony is that of Eusebius, who mentions fourteen epistles as being clearly and certainly Paul's, but adds that "some have rejected that which is written to the Hebrews, alleging, with the church at Rome, that it is spoken against as not being Paul's." He frequently cites it as written by Paul. The Western church seems to have been greatly divided on this subject from about the close of the 2nd to the middle of the 4th century, when Jerome states that the Epistle was received as Paul's by all the Greek and some of the Latin churches, though rejected by most of the Latins, who ascribed it to Barnabas or Clement of Rome, but held it in high esteem, and read it in their churches. Jerome himself, and Augustine, constantly refer to it, sometimes as an apostolic production, and sometimes as St. Paul's. Their authority appears finally to have established the belief in its Pauline origin among the Western churches. The modern advocates of the same opinion have attributed the doubts which prevailed in the Western church at the end of the 2nd century to the disputes with the Montanists, who relied on this Epistle in support of some of their opinions. On the other hand, those who believe that Paul did not write the Epistle ascribe the strong testimony of the Alexandrian fathers in its favour to their great fondness for the allegorical interpretation of Scripture, which the style of this Epistle is thought to sanction. The passage in 2 Peter iii. 15, is thought by some to refer to the Epistle to the Hebrews.

The internal evidence in favour of Paul being the author is drawn from the reference (c. xiii. v. 23) to Timothy, who is known to have been Paul's intimate friend and frequent companion; and from other incidental allusions (see x. 34; xiii. 18, 19, 24). In the arrangement of the Epistle, the former part being doctrinal and the latter part hortatory; in the mode of using quotations from the Old Testament and the style of argument adopted; in the doctrines most prominently stated and the phraseology employed; there are great resemblances between this book and St. Paul's acknowledged epistles. (For examples see Prof. Moses Stuart's 'Commentary on the Hebrews,' Introd., sects. 20–24, and Horne's 'Introduction,' vol. iv., p. 415, &c., ed. 1834.) The chief objections against the Pauline origin of the epistle are drawn from the absence of the usual address at the beginning, the superiority of the style to that of Paul's acknowledged epistles, and the resemblance between its style and that of the Alexandrian school. The points above stated are discussed with great ability and candour by Prof. Moses Stuart in favour of the Pauline origin of the epistle, and Prof. Bleek ('Der Brief an die Hebräer') on the other side. On the whole, the arguments of St. Paul being the writer seem to be irresistible.

The opinions which assign the authorship to Barnabas, Apollos, Luke, and Silas, rest on very slight grounds. The second of them was first started by Luther, a conjecture founded on the resemblance which the epistle bears to what we might expect to have been written on such a subject by a man of the character given to Apollos in Acts xviii. 24–28.

The date depends partly on the settlement of the former question. The internal evidence of the Epistle shows that it was written while the temple at Jerusalem was standing (see viii. 4–5; ix. 9), and probably not long before its destruction in A.D. 70. If Paul was the author, it was probably written during his first imprisonment at Rome, and immediately before he was released (see xiii. 18, 19, 23). Accordingly most critics refer it to A.D. 61 or 62; some say A.D. 58.

The canonical authority of this Epistle depends partly on its authorship; but may be argued on other grounds. It is repeatedly quoted by Clement of Alexandria, and apparently by Barnabas, Hermas, Polycarp, Ignatius, and Justin Martyr. It is contained in the Peshito Syriac version, the date of which is not later than the 2nd century, and in the old Latin versions made about the same period. From that time the questions of the canonical authority and the authorship are very much mixed up together.

The design of the writer of this Epistle appears to have been to sustain the faith of those to whom he wrote, while they were suffering under persecution and inclined to apostacy. After urging them to the practice of various Christian duties, he concludes with the usual salutations. In warmth of feeling, elegance of language, and force of argument, this epistle yields to no book of the New Testament.

The separate commentaries on this book are extremely numerous. Among the more recent are Barnes's 'Notes, Practical and Explanatory,' 1843; Tholuck's 'Commentar sum Briefe an die Hebräer,' 1840; the 'Commentar zum Briefe an die Hebräer,' 1858, of Delitzsch. In Kitto's 'Cyclopædia of Biblical Literature,' a list of commentators is given.

HECATE, one of the ancient Greek divinities, the daughter of the Titan Perses and Asteria, according to Hesiod ('Theog.,' 411), but others give to her a different parentage. She appears to have been originally a Thracian deity, and regarded as a Titan of unusual powers. She was a mystic goddess, and identified, more or less, with several ancient Greek deities, but her attributes correspond in most respects with those of Artemis; and it has therefore been conjectured that she may originally have been the same as Artemis. Her name, the feminine of Hecatus ("the far-shooting"), one of the names of Apollo, the brother of Artemis, is thought to favour this supposition. Hecate presided over hunting and fishing, the deliberations of the popular assembly and the courts of justice. She seems also to have appropriated to herself part of the duties of Persephine (Proserpine); since she was regarded as the mistress of the lower world, the arbiter of the souls of the departed, and the patroness of magic. She was considered a beneficent deity, who answered the prayers of her worshippers. Her statues were placed at cross-roads and before houses. She was held in much respect in Athens, where she was regarded as the patroness of families and children. She was greatly venerated by the inhabitants of Ægina, who held a festival once a year in honour of her; which was said to have been instituted by Orpheus. (Pausan., ii. 30.) Representations of her are very numerous. Sometimes she appears as a three-headed being, attended by the Stygian dogs; sometimes with three bodies, when she is the same as the Diana Triformis of the Romans (Virgil, 'Æn.' iv. 511). We give an engraving of Hecate (or Diana Triformis), from a votive statue, 2 feet 6 inches high, in the

British Museum. Statues of this kind were placed in towns and villages where three roads met. The figures held various symbols, as a globe, a patera, twisted cords, serpents, a torch, &c. The hands with the attributes in the Museum statue, are however modern.

Statue of Hecate from the British Museum.

HEDERIC ACID. An acid, of uncertain composition, extracted from ivy-berries. It crystallises in needles or thin plates, which are colourless and inodorous, but possess the intensely bitter taste of the ivy. It is insoluble in water and ether, but soluble in alcohol. In contact with concentrated sulphuric acid it strikes a fine purple colour.

HEDERINE. An alkaloid found in ivy-berries. It requires investigation.

HEDGE, one of the most lasting and effectual of our fences. When hedges have been well made, and are kept in good order, nothing can surpass them, except well-built stone or brick walls, and even these are far less effectual in keeping out trespassers of every description.

Hedges are made of various kinds of shrubs and trees, trained so as to throw out numerous branches along the stem from the surface of the earth upwards; this is done by judicious pruning when they are young. The head being cut off and the side branches shortened, numerous smaller branches spring out, which are shortened in their turn, and form a very compact mass, consisting of the ends of stumps and branches pointing in every direction. Those shrubs which are of a thorny nature are best adapted for hedges. Holly, which bears prickles on the edges of the leaves, is on this account by far the best shrub to form a hedge. But it has a great inconvenience in its very slow growth, and except in very old gardens, which have been surrounded by a holly-hedge before the present generation was born, it is very seldom that such a hedge is met with. The high price which the nurserymen charge for this plant is another reason why it is seldom planted.

In forming a holly-hedge the ground should be prepared by trenching and abundant manuring: the plants should be most carefully planted after midsummer, or immediately before the usual rains which come at that season. There should also be a portion of virgin soil for the roots to spread in; and in planting they should be well divided, to give them the greatest extent from which to draw their nourishment. The earth should be well pressed to them by treading it down; and in case of a continued want of rain, they may be occasionally watered, late in the evening, or early in the morning. By a little attention to them in the first year, they will form a good fence several years sooner than those which are comparatively neglected. The plants which are usually put in are three years old; but if they could be transplanted at once from the seed-bed, they would sooner come to perfection; and by being cut down and pruned earlier, would lay the foundation of a closer and better hedge. Next to holly, as forming a close and durable hedge, is the yew: it bears very close clipping, and forms a thick hedge and good shelter all through the year. For gardens and nursery-grounds, where shelter and occasional shading are required, the yew-hedge is preferred; but in all places where cattle are put to pasture, the yew should never be permitted to grow. Many valuable horses and cattle have been destroyed by grazing in places where yew-trees grew; and notwithstanding the instinct which leads animals to reject food which is hurtful, they greedily eat the yew leaves in spring. The same may be said of box.

The various kinds of thorns are peculiarly adapted to form hedges, and they are consequently by far the most common plants of which a live hedge is formed.

For high hedges and strong fences the hornbeam and a variety of the beech which throws many branches from the stem are extensively used in old gardens, where geometrical figures and numerous angles are admired.

Where it is desirable that the hedge should arrive very rapidly to such a size as to be a good defence against cattle, elder may be planted. Elder grows very rapidly, and throws out many long hollow branches, which soon become hard, and are admirably calculated for a fence, and cattle will not eat the leaves; but it is never very close or ornamental; and as it requires to be cut down frequently, it displays very unsightly knots and stumps when it has acquired a certain age.

Sweetbriar is ornamental, and forms a good fence against sheep. It is chiefly confined to flower-gardens and enclosures in pleasure-grounds.

Many other shrubs might be named, such as the *Pyrus japonica*, which is prickly, grows close, and bears a beautiful flower. It is as hardy as any native British plant, and will bear cutting and training as well as any of them. Hitherto no hedges have been made of this shrub, except a few in the gardens of nurserymen; but there is no doubt that if many young plants were wanted for hedges, they would soon be produced at a reasonable price. The privet is a very common and quick-growing shrub, which is frequently planted as a hedge where cattle are not admitted; but of all shrubs, the most common and most useful for the purpose of hedges are the black and white thorn, and they almost universally form the quick hedges by which our fields are separated and enclosed.

In order to have a good hedge, the shrubs should be planted in a soil which is naturally strong, but well pulverised, and in which no shrub or tree has lately grown. The best soil is that which is produced by the decomposition of sods taken from commons or old pastures; and it is observed that in new enclosures, where the quick has been inserted between two sods, it always grows luxuriantly, and only requires to be protected, when young, against the cropping of cattle and sheep, which are fond of the young tender shoots. The usual mode is to insert, in the early part of the spring, a row of quick in the side of the bank, on a level with the surface of the ground, where a sod has been turned over, and forms the base of the bank raised by the earth taken out of the ditch. This quick requires to be protected from cattle or sheep by some fence. [FENCE.] Sometimes the quick is planted in two or three parallel rows on the top of the bank, which in this case is made much wider, with a ditch on each side. A double fence in such case is necessary for its complete protection. When the quick is planted on the top of the bank, the surface sods are reserved to lay at the top; and after being broken and chopped to pieces, are dug into the bank. Stable-dung is frequently dug in at the same time, and is well bestowed: the quicks are then inserted, and well watered. They never fail to come up luxuriantly; and when properly pruned they form a close and impenetrable hedge.

Many think that it is advantageous to prune and cut down the young shoots every year, in order to excite them to throw out fresh ones in greater number. But this is an error, by which the growth of the hedge is much retarded. The shoot should be allowed to grow to its full extent the first and second year; the root will then have struck deep into the ground; and in the third or fourth year the quicks may be cut down to a few inches. They will then send out several fresh strong shoots, which may be cut and pruned to the height and width of the intended hedge.

In Holland and Flanders the hedges are often trained along stakes and rods placed for the purpose, and tied together with osiers. In this case every slender branch is tied to the rods, and they are laid so as to cross each other frequently, and the redundant shoots which cannot be conveniently tied in are cut off. These hedges, when in leaf, look very close and light, and take up very little room; and birds can scarcely harbour in them. It appears at first sight that much labour is required to train hedges in this way; but this is by no means the case. When they have once grown to the proper height they only require to be regularly clipped.

In forming a hedge it is necessary to take into consideration the quality of the soil, the aspect of the bank, and whether the land is porous, or very retentive of moisture. In the first case it will be advantageous to plant the quick in the side of the bank, raising the earth above it to keep in the moisture. A ledge may be made by setting the first sod at a couple of inches from the edge of the ditch.

The water which may fall on the bank and run down the smooth side is arrested by the lodge and soaks into the roots. In the other case the top of the bank is the proper place, and a small concavity may be given to it to retain the water and keep the roots moist.

In a dry soil which does not require draining, ditches are unnecessary, and it is much better to plant a hedge on a little bank formed by a few sods about eighteen inches wide, with a small water-furrow on each side. The whole width need not be above two feet six inches, whereas a bank and ditch take up at least six feet, and the plough cannot go nearer than a foot from the edge of the ditch or the bank. Thus eight feet are taken up by the fence.

When a hedge has been left uncut for several years, it grows wide and high. It requires to be cut down once in seven or eight years; in this case much care is required in the cutting that the shoots may grow out again regularly. The common labourers often do this very carelessly, by cutting the stems downwards with one or more cuts of their bill-hook. The consequence is that the stem is split and shivered, and the rain lodging in the ragged cut injures the wood and causes it to die down farther than it otherwise would. Hence the general maxim of "cutting up," so strongly recommended by all those who give directions about cutting hedges. Portions of the stems are often left of a greater length than the rest for the purpose of holding the bushes, which are generally laid over the cut stumps to protect them against cattle. But it is better to cut the hedge regularly, one row close to the ground, and one a few inches longer; this will strengthen the foot of the hedge, and prevent its being thin and hollow at bottom.

When a hedge has become old, and many of the plants are decayed, it is very difficult to renew it. If young quicks are planted on the same spot, they will scarcely ever succeed, unless very great precautions are taken. The soil is exhausted or deteriorated, and must be renewed: but manuring is not sufficient; fresh earth is required for the new quick. The simplest process is to level the old bank, spread the earth of which it was formed, which will be of great use to the ground where it is spread, and form a new bank in the same place from earth taken elsewhere; or, where it can be done without inconvenience, it is better to make an entirely new ditch and bank, and to fill up the old. This is perhaps the surest as well as the soonest way of having a new hedge which will be permanent.

What has been said of renewing a hedge is equally applicable to repairing gaps in an old one. It is of no use to put in young plants in the old bank. The earth must be removed, and fresh earth put in its place. The old hedge must be cut and trimmed, so that the young quick may not be shaded, and in that case the gap will shortly be filled up, and the hedge be restored as a continuous fence. Where the gaps are very small, and the hedge is not cut down altogether, it may sometimes be advisable to plant hollies or other plants, which will grow well and fill up the deficiency.

Well managed hedges are the most effective fences, the cheapest, and the most pleasing to the eye. It is to the hedge-rows that England owes much of its garden-like appearance; but the trees, which are their chief ornament, are very destructive of the hedge as a fence; and where trees are planted it would be much better if they stood within the bank, without interfering with the hedge. Whether trees can be allowed in hedge-rows, in a perfect system of agriculture, is a question which we will not attempt to answer.

There is a method of repairing hedges which is called "plashing" (*pleaching*). It consists in cutting half through some of the stems near the ground, and then bending the upper parts down in a horizontal or oblique position, keeping them so by means of hooked sticks driven into the bank. Thus a live hedge is made, which fills up the gaps in the same manner as a dead hedge would have done, and the bent stems soon throw out shoots. If the stems are young, and not above the thickness of a finger, an excellent hedge may be thus formed, which, when clipped, will be close and perfectly impervious. But the work is generally done in a very injudicious manner. When a hedge is plashed which has been long neglected, the thick stems, which are hacked through, leaving only a small portion of the under bark uncut, have an unsightly appearance, and seldom throw out shoots near the bottom, where they are most wanted. To plash a young hedge by merely bending the twigs is an excellent practice: but when the stems are thick and old, the only remedy is to cut them down, or make an entirely new bank well planted with quick.

HEIGHTS, MEASUREMENT OF. There are three very distinct ways by which heights may be measured. The first is by observation of the angles of elevation of objects, supposing their distances to be known, which is explained roughly in works on trigonometry and mensuration, and with more precision in those on geodesy. [MENSURATION.] The second serves for the measurement of heights in cases where not only the height of a summit is required, but also that of the slope which leads to it, at different distances from the summit; and this is done by means of the level. [LEVELLING.] The third, which we propose here to describe more particularly, is accomplished by means of the barometer. [BAROMETER.] We may also refer to a fourth method, depending on the diminished temperature at which liquids boil under diminished pressures: for the experimental details of this method, see BOILING OF LIQUIDS.

If we ascend with a barometer through any height, the weight of the column of air which presses on the instrument is diminished, and the counterpoise, namely, the column of mercury under the vacuum, must diminish likewise; that is, the mercury must fall. The amount of this fall depends upon the height in question: and when the relation between the two is perfectly well ascertained, may be made the means of determining it. If the temperature at the higher and lower station were the same in all places and at all times, and if the force of gravity were precisely the same at all heights, one formula would serve for all times and for different places, if the height of the barometer remained always the same at the same height above the sea. In such a case, one observation made in London a hundred years ago, combined with one made at Quito in the present time, would serve to determine the difference of level between those two places. And even as it is, the mean height of the barometer at the two places, when known, could be made to determine the point. But when only one or two observations can be made at each place, the differences of temperature, &c., must be noted and allowed for: and this necessity renders the numerical operations connected with the solution of the problem more intricate than they would otherwise be.

If the temperature were unaltered during the ascent, and the force of gravity also remained uniform, the *logarithms* of the atmospheric pressures corresponding to different altitudes would *decrease* in arithmetical proportion as the altitudes themselves *increase* in arithmetical proportion; that is, the density of the atmosphere *decreases* in a *geometric* progression, as the heights *increase* in an *arithmetic* progression. Thus if at altitudes 0 and h the logarithms of the pressures were k and $k-l$, at an altitude $2h$ the logarithm of the pressure would be $k-2l$, and so on. And since the height of the barometer is proportional to the pressure for the time being, this would lead to an equation of the form

$$z = c\,(\log. h - \log. h');$$

where z is the difference of altitudes at two stations, and h and h' the heights of the mercury at the lower and upper stations.

The constant c might be determined either from theory or actual measurement; for if h and h' were known in any one case, and also z by trigonometrical or other measurement, c might be determined, and being independent of z, h, and h', would then be known in all cases. But in truth c is not to be thus determined, for though independent of h and h', it varies with temperature, the force of gravity, &c.

1. If the temperature either of the higher or lower stations be not the same in different observations, the multiplier c will be of one value or another, depending on the temperatures.

2. If the mercury be not of the same temperature at all times, its specific gravity will vary, so that a given column of it will not represent the same atmospheric pressure at all times.

3. If the force of gravity be taken into account, the pressure taken off by the ascent will be a larger proportion of the whole pressure than was supposed in the investigation of the preceding formula, since it is taken from the part of the atmosphere where the force of gravity is greatest. This is independent of its greater weight as being taken from the densest part of the atmosphere. The latter circumstance has been already taken into account in the formula, and from it comes the law that the logarithms of the pressures diminish in arithmetical progression, since the pressures themselves would diminish in arithmetical progression if the density of the air were the same at all heights.

4. Bessel has recently shown that another correction must be applied, owing to the modifications produced by the existence of a humid atmosphere of peculiar habitudes, *within* the dry or permanently elastic one. After applying all these corrections, the formulæ are determined by the aid of subsidiary or *hypsometric* tables, the best of which are those by Deleros, published in the 'Annuaire Meteorologique,' for 1849. Those containing *also* Bessel's correction are given in the same work by Plantamour, for 1852.

We now proceed to describe two formulæ made on slight differences of hypothesis as to the element of the problem about which we know least, namely, the law of variation of the temperature of the atmosphere. The first formula, which is nearly in the form given by Laplace, is taken from Poisson's Mechanics, and supposes that the air intermediate between the higher and lower stations may be treated as if it had throughout the mean between the temperature of the two stations. The second, taken from Lindenau's Barometric Tables, is on the supposition (which was also made by Euler and Oriani) that the temperature of the air diminishes in harmonic progression through a series of heights increasing in arithmetical progression.

Let h and h' be the heights of the barometer at the lower and upper stations; t and t' the temperatures of the air; T and T' those of the mercury (ascertained by a thermometer whose bulb is in the cistern); r the radius of the earth, and λ the latitude of the place. All the temperatures are in degrees of Fahrenheit. Let

$$=h\left(1+\frac{\mathrm{T}-\mathrm{T}'}{9990}\right)$$

$$c=\frac{60168}{1-\cdot 00257\cos 2\lambda}\left(1+\frac{t+t'-64}{900}\right)$$

$$z=c\,(\log. h-\log. k).$$

Then z itself is a near approximation to the number of yards in the difference of level between the two stations; but if a more exact one be required, it may be found by calculating (using z itself as just found)

$$z = c\left(\log. h - \log. k + 2\log.\left(1 + \frac{z}{r}\right)\right)\left(1 + \frac{z}{r}\right)$$

When the lower station is at a great distance from the higher on the earth's surface, then five-eighths of $\frac{z}{r}$ should be used instead of $\frac{z}{r}$ in the last formula.

The second formula, by M. Lindenau, is as follows, the letters meaning the same things as before; but the degrees are those of Réaumur's thermometer, and the distances are expressed in toises. The toise is 2·1315308 English yards, and a reading of Réaumur is reduced to one of Fahrenheit by the following formula:—

$$\text{Fahr.} = 32^\circ \frac{9}{4}\ \text{Réaum.}$$

$$\text{Let } c = \left(1 + \frac{t+t'}{400} - \frac{(t-t')^2}{160000}\right) \times 9442;$$

$$\text{H} = h\left(1 - \frac{\text{T} - 10}{4329{\cdot}6}\right)$$

$$\text{H}' = h'\left(1 - \frac{\text{T}' - 10}{4329{\cdot}6}\right)$$

Then the number of toises in the difference of elevation of the stations is

$$c\,(\log. \text{H} - \log. \text{H}').$$

The formula which has been generally used is of the form

$$z = a\left(1 + \frac{t+t'}{b}\right)(\log. h - \log. h');$$

and the following are the constants a and b used by the observers whose names are mentioned, all reduced by M. Lindenau to those values which they should have when the thermometer is Réaumur's and the result in toises:—

Ramond	$a = 9437$	$b = 400$
Trembley	$a = 9401$	$b = 361$
Roy	$a = 9388$	$b = 362{\cdot}2$
Schuckburgh	$a = 9400$	$b = 366{\cdot}6$
Deluc	$a = 9220$	$b = 396{\cdot}4$

The preceding are the most exact formulæ for computing the heights required. The late Prof. Leslie has, however, given the following rule, as the simplest approximation for all practical purposes:—"As the sum of the heights of the mercurial columns is to their difference, so is 52,000 to the approximate height in English feet." Lastly, the most complete accounts of this subject will be found in Schumacher's 'Astronomische Nachrichten,' band xv.; by Bessel, and in Biot's 'Astronomie Physique,' tom. iii. Prof. Littrow has given in the first volume of the 'Astronomical Society's Transactions,' a very beautiful method, which dispenses with the use of logarithms.

HEIR, by the law of England, is he who succeeds by right of blood to the real property or lands, tenements, and hereditaments of the deceased owner, designated by the correlative term of ancestor, not given away from him by will. The English law which determines the succession to personal property, when uncontrolled by local custom, is contained in the statutes of distributions (22 & 23 Chas. II., c. 10; 29 Chas. II., c. 3; and 1 Jac. II., c. 17), which are founded upon the provisions of the civil law. The persons so entitled are not called heirs, but next of kin.

The several rules of descent which regulate the right to succeed to real property spring from the system of feudal tenures, but have been somewhat modified by the statute of 3 & 4 Wm. IV., c. 106. [DESCENT; ENTAIL; ESTATE; FEUDAL SYSTEM.]

Heir-at-law, or heir-general, is he who succeeds according to the rules explained in the article DESCENT, where there is no will of his ancestor and no instrument which determines a special course of descent. Heir-special is he who succeeds in the order pointed out by some instrument which determines such special course of descent. [ENTAIL.] Heir-apparent is he whose right of inheritance is indefeasible, provided he outlives his ancestor; as the eldest son. Heir-presumptive is he who, if his ancestor should die immediately, would in the present circumstances be his heir, but whose right of inheritance may be defeated by the birth of some nearer heir; the brother or nephew of a man who has no children is heir-presumptive. Heir by custom is he whose right as heir is determined by certain customary modes of descent, which are attached to the land. [DESCENT; COPYHOLD; GAVELKIND.]

The expression "heirs by devise" has also been sometimes used, though such are not strictly heirs according to the English law; but have been so called inaccurately after the *heres factus* of the Roman law.

The rules of the civil law upon the subject long prevailed in Scotland, both in principle and practice. But various alterations have been made in the Scotch law of inheritance, and now the different descriptions of heirs are far more numerous than in either the English or the Roman law. Heirs-at-law are called heirs whatsomever. Heirs-in-tail, heirs of tailsie, and heirs of provision differ little in their nature. There are also heirs active, heirs by conquest, heirs of line, heirs passive, heirs male, and heirs portioners, the particular distinctions between each of whom it is not necessary here to describe. (See Bell's 'Commentaries and Principles,' and Lord Kames's 'Law Tracts.')

The French law of descent has followed the Roman law, and the obligations and privileges of the heir are essentially the same as there prescribed.

In America the English law of descents has been in most instances rejected, and each state seems to have established rules for itself. There is no entire information upon this subject; indeed chief-justice Reeve in the preface to his 'Treatise on the Law of Descent in America,' has this strong passage, that the nation "may be said to have no general law of descents, which probably has not fallen to the lot of any other civilised country." (Kent's 'Commentaries,' lect. 65.)

The term *heres* in the Roman law has a very different signification from the term *heir* in the English law. The Roman term *hereditas* denoted all the rights and obligations of a testator or intestate; and the *heres*, when his title as such was completed, represented the person of the testator or intestate, and as a consequence succeeded to all his rights and obligations. A man might by his will appoint one *heres* or more, and the property of an intestate might devolve on one *heres* or more; but this made no difference with respect to their character. Each person was *heres* in proportion to his share of the inheritance. The *heres* appointed by will was called *scriptus*, or *factus*, or *testamentarius*; the *heres* who succeeded in case of intestacy, *ex lege*, or *legitimus*, that is, appointed by the law, or *ab intestato*.

An important distinction between *heredes* as established by the old Roman law was this, and the distinction was the same (so far as it could be applicable) both in the case of testacy and intestacy. All persons who were in the power (*potestas*) of the testator, or intestate, during his lifetime, such as children not emancipated, and slaves, were obliged to accept the inheritance with all its burdens; the inheritance, in fact, devolved upon them by the will of the testator, and no act of assent on their part was necessary. Other persons, not in the power of the testator, were only bound to undertake the burden of the testator's debts in case they accepted the inheritance, for which purpose their express assent was necessary. But by the legislation of Justinian, the *heres* in all cases was only answerable for the debts of the testator or intestate to the amount of property which such testator or intestate left behind him, of which, however, the *heres* was required to make an inventory within a certain time. ('Cod.' vi.; 'Tit.' 30, l. 22; 'Instit.' ii. 19.)

The discussion of the various rights and duties of the Roman *heres scriptus* belongs to the subject of wills.

In the case of intestacy, the distribution of the property was analogous to the distribution of an intestate's personal estate by the English law. The Roman law gave no preference to an eldest son over a younger, or to a brother over a sister. Emancipated sons, who, by the strict rule of the civil law, were excluded from the inheritance [EMANCIPATION], were placed by Justinian's legislation on the same footing as children not emancipated. It is unnecessary here to state more minutely the rules which regulated the distribution of an intestate's property. ('Instit.' iii. 1; 'Nov.' 118, c. 1, 2, 4.)

It is important to conceive clearly the fundamental notion of the difference between the Roman *heres* and the English *heir*. The Roman *heres*, when his title to the inheritance was completed, represented the person of the testator or intestate, and so far corresponded to our executor or administrator. His title to the property, as *heres*, was absolute, and derived entirely from him to whose rights and obligations he succeeded. The English *heir*, according to the strict principles of tenure, derives his title to the land not from his immediate ancestor as such, but by virtue of his relationship by blood to the person who acquired the land, deduced through his immediate ancestor. The consequences which flow from these two different notions of the Roman *heres* and English *heir* are numerous and important. They are well stated, in a general way, by Mr. Butler in his note on 'Coke-Litt.,' 191 *a*. The stat. 4 Wm. IV. c. 104, which makes all a deceased person's estate in land liable to the payment of his debts, has materially affected the ancient right of the English heir.

HEIR-LOOMS are such goods and personal chattels as, contrary to the nature of chattels, go to the heir by special custom along with the inheritance, and not to the executor of the last proprietor. [CHATTELS.] They are principally such things as cannot be removed without damage to the inheritance, as chimney-pieces, fixed tables, &c. Deer in an authorised park, fishes in a pond, deeds, charters, and court-rolls, together with the chests in which they are contained, are heir-looms. And so it seems are journals of the House of Lords in the possession of a peer. By special custom in some places, carriages also and household implements may be heir-looms.

The termination "loom" is of Saxon origin, in which language it signifies a limb or member, so that an heir-loom is nothing else but a limb or member of the inheritance. (2 Bl. 'Com.') Chattels are sometimes directed by testators to go to the heir, together with the inheritance, as heir-looms, and though it is the duty of the executors to carry the intention into effect so far as they can, yet the direction does not affect the rights of creditors, neither can it effectually prevent the devolution of the chattels according to their real nature.

HELIACAL (ἥλιος, the sun), a term applied to the rising of a star, when it takes place just before that of the sun. If we suppose a star not very far from the sun's orbit, then as the sun approaches that star it will become for a season permanently invisible, for it will rise after the sun, and set after it also, the heavens remaining too light in the quarter of sunset to permit the star to be seen. But as soon as the orbital motion of the sun has carried it past the star, the latter will begin to rise first, and in process of time will rise so much before the sun as to become visible just before daylight. In this case it is said to rise helically: thus a star sets heliacally before its season of disappearance, and rises heliacally after its reappearance. The successive heliacal risings of stars thus form a continued warning of the seasons, and were used for this purpose among some ancient nations. But since the precession of the equinoxes slowly changes the offices of different stars with respect to the seasons, an ancient record of the time of the year when a given star rose heliacally would enable us to make a rough guess at the number of centuries elapsed since the time of the observation. Upon such a basis Newton rested a great part of his system of chronology, taking the descriptions of the heliacal risings of stars from Hesiod.

HELIACAL CURRENTS. [Electro-Dynamics; Electro-Magnetism.]

HELICIN. [Salicyl.]

HELICOIDIN. [Salicyl.]

HELIOCENTRIC (having the sun as centre), a term applied to the place of a planet, as seen from the centre of the sun, in opposition to its *geocentric* place, as seen from the centre of the earth. [Parallax.]

HELIOMETER (ἥλιος, the "sun," and *μέτρον*, "measure") is the name given by M. Bouguer to a micrometer invented by himself about 1745, by means of which the diameters of the heavenly bodies may be measured with considerable accuracy. In Bouguer's construction the tube was of a conical form, and provided with two object-glasses of equal focal length, which were so adjusted as to admit of being moved in a direction transverse to the axis of the tube; or the object-glass was cut into two parts through a diameter, these two parts being relatively moveable. By this contrivance the two images which are formed in the focus of the eye-glass may be made to diverge, coincide or lap over each other, by merely varying the distance between the centres of the object-glasses, and this distance is indicated by a graduated scale attached to the tube. When the two images coincide, the angle subtended by the observed objects will be equal to that subtended by the centres of the object glasses, which being known, the magnitude of the observed object may readily be computed when its distance is given, or the distance determined when its magnitude is given. As this instrument does not differ in principle from the divided object glass micrometer, the reader is referred to the article Micrometer; and for further information relative to the invention, see the 'Mémoires de l'Académie Royale des Sciences,' 1748, p. 11. [Bouguer, in Biog. Div.] It is necessary, however, to refer to the noble instrument at Oxford, constructed by M. Repsold, and placed under the management of Professor Johnson. This heliometer is mounted as an Equatorial, with the hour-circle at the top of the pillar, and the declination circle at one end of the axis, both within reach of the observer. The divided object-glass is 7·5 inches in diameter, and has a focal length of 10·5 feet. It is cut into two semicircles by a section along a diameter, and the two pieces are made to slide along their common section by means of micrometer screws, connected with graduated scales. Rather than attempt to describe this instrument and the valuable work performed by it, which would be necessarily imperfect in our limited space, we think it best to refer to the 'Radcliffe Observations' for 1851, in which volume, and the previous one, the structure and use of the Oxford heliometer are ably discussed by Professor Johnson. There is also the celebrated memoir by Bessel in the 'Königsberg Observations,' and the dissertation by Brunow in his 'Späzische Astronomie.'

HE'LIOS (Ἥλιος), in the Greek, *Sol* in the Roman, mythology, the sun-god, was the son of Hyperion and Theia, or of Hyperion and Euryphaessa. Homer speaks of Helios as ascending the sky daily from Oceanus to give light to gods and men, and again descending by the western gate. Later writers enlarge much on the glory of his abode; or describe him as sailing during the hours of the night round half the globe in a vessel of gold, the gift of Hephæstus, and wrought by his hands, or softly sleeping on a golden couch. The chariot of Helios was a quadriga; his horses fed upon herbage growing in the blissful isles. By Homer, Helios is spoken of as seeing all that is done by men and gods, and hence he was able to give notice to Demeter of the abduction of her daughter Persephone, and to warn Hephæstus of Aphrodite's infidelity. His flocks were kept in the sacred isle of Thrinacia, in Sicily. Temples appear to have been erected to Helios in many parts of Greece; bulls, horses, goats, rams, and other animals, usually white, were sacrificed to him. Helios was especially honoured at Rhodes. Representations of him were engraven on the coins, both full-faced and in profile, surrounded with rays of light, or having streaming ray-like hair. The famous Colossus of Rhodes was a statue of Helios, 70 cubits high. In the later ages Helios was to a great extent confounded with Apollo.

HELIOSCOPE (a Greek term signifying literally "sun-observer") is a kind of telescope, adapted for making observations upon the sun without the eye being injured by the intense brightness of the solar rays. Dr. Hooke wrote a treatise in 1742 expressly on the subject of helioscopes, wherein he recommends four reflecting glasses to be so placed within the tube of the telescope that the solar rays may suffer four reflections before they strike the eye, and thus, he observes, their intensity will be reduced to the 256th part of their original intensity. Hevelius and other philosophers preferred the use of coloured glasses, which is the common practice of the present day; while Huygens merely blackened the inner side of the eye-glass by holding it over the smoke of a lamp or candle.

HELIOSTAT, an instrument used for making a solar beam appear stationary, or rather preserve an invariable direction, notwithstanding the motion of the sun in the heavens. Such an instrument is necessary to persons engaged in the higher branches of optical research, and its principle rests on that of the Equatorial. There is a reflecting surface connected with a polar axis, which is moved by clock-work at the rate of the sun's diurnal velocity, so that the ray thus reflected is constant in direction: whence the name of the instrument, from ἥλιος the sun, and *ἵστημι* to stand still. Of course the ray thus obtained may be received by a second mirror, and turned in any required direction. There is a good description of a heliostat in the second volume of Biot's 'Précis Elementaire de Physique,' also in Pouillet's 'Physique,' and Frick's 'Physikalische Technik.'

HELIOTROPE, an instrument used, chiefly abroad, in geodetic surveys, to enable the surveyor to transmit signals of reflected light from one station to another, and to perceive with facility the signals transmitted. M. Merz, of Munich, is said to have contrived the most convenient form of this instrument.

HELIX. [Screw.]

HELLEBORINE. A vegetable alkaloid of unknown composition contained in the root of the black hellebore. It resembles *piperine*.

HELLEBORUS NIGER (Black Hellebore, or Christmas Rose.) The root of *H. Niger* is now the officinal one, and it is to be regretted that many other roots, especially those of *Actæa spicata* and *Adonis vernalis*, are often intentionally or accidentally sold in its stead. These may be discriminated by physical characters (particularly the internal structure), and by chemical tests. The activity of hellebore seems to reside in its resinous matter, for which rectified (not proof) spirit is the proper menstruum.

Like most ranunculaceous plants hellebore can occasion rubefaction and inflammation of any surface with which it is brought in contact; when taken into the stomach in a moderate dose it gently stimulates it and the other viscera of the abdomen; but in large doses it is a fatal poison. It is a dangerous medicine, and one which is rarely necessary to have recourse to.

The hellebore of Hippocrates, Dioscorides, and other ancient writers, famous for the cure of insanity, is not the plant mentioned above, which is a native of southern Germany, the Apennines, also of Laconia and Mount Athos. The plant of the ancients is called by Dr. Sibthorp, *H. officinalis*, by Decandolle, *H. orientalis*; it is found on Mount Olympus, Helicon, and the island of Anticyra. Its purgative properties occasionally rendered it useful in madness.

HELLENENE. [Hellenin.]

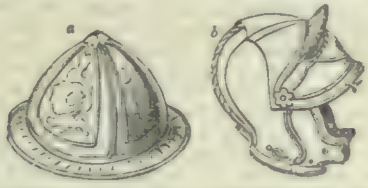
HELLENIN ($C_{42}H_{28}O_{6}$) is a concrete volatile principle, allied to the essential oils. It is a solid crystalline body, and is obtained from the *Inula Helenium*. With nitric acid it yields *nitro-hellenin*, whilst anhydrous phosphoric acid converts it into a hydrocarbon *hellenene* ($C_{36}H_{26}$).

HELM WIND. [Wind.]

HELMET, an ancient armour of defence for the head, still worn by the officers and soldiers of some of our cavalry regiments. Its original name was Helm, possibly borrowed from the Latin (of the lower age) *helmus*. Skinner however derives it from the Anglo-Saxon verb *helar*, to hide. "Helm" certainly occurs both in Cædmon's 'Paraphrase,' and in the Saxon Gospels, as well as in Ælfric's 'Glossary.' *Helmet* was probably adopted, in the middle age, from the Italian *elmetto*.

As a part of defensive armour the helmet is of high antiquity: some sort of covering of this description for the head appears to have been worn by the warriors of every country. Helmets were found even among the inhabitants of the South Sea Islands when discovered by Captain Cook. Among the oldest specimens now remaining are probably the two helmets found on the field of Cannæ in 1752, preserved in Sir William Hamilton's collection in the British Museum. Another ancient helmet, bearing an inscription, found at Olympia, was presented to the British Museum by King George IV.

The form of the Greek helmet and its general description may be collected from various passages of the Greek writers, from Homer downwards, and more especially from the medals and marbles on which it is represented. We give the representation of one from a terra-cotta in the Townley Collection in the British Museum, showing the heads of Athene and Zeus. In the same collection are others of Athene, and also one of Pericles. It does not appear that the Greek or Roman helmet usually protected the face. Both the helmets found at Cannæ, however, protected the face, and have projecting nasals. A helmet found at Pompeii (and now in the collection at Goodrich Court) has the nasal projection. Lipsius's treatise 'De Militia Romana' (iii., c. 5), contains a full account of the Roman helmet, with which the reader may compare the plates and descriptions in the third volume of Count de Caylus's 'Recueil d'Antiq.' For the helmets in more modern use, Grose's 'Treatise' and Meyrick's 'Critical Account of Ancient Armour' must be referred to. Among the varieties which had separate names we find the Chapelle de Fer, the Bacinet, the Burgonet, the Castle, the Hufken, the Morion, the Salade, and the Skull. These were almost invariably of steel. There was also the Justing Helmet, used in tournaments, which was sometimes of leather.



a, Morion ; *b*, Burgonet ; of the time of James I.

The *nasal*, the *ventaile* or moveable front, the *visor*, lifted up by pivots, and the *bevor*, to allow of drinking, were the names of parts of certain helmets introduced at different periods, and not always used.

As ornaments over the shield or coat of arms, helmets are still used in heraldry. The full-faced helmet with six bars, all of gold, damasked, is for the sovereign and princes of the blood; the full-faced helmet of steel for marquises and dukes; earls, viscounts, and barons have a profile or side-standing helmet of steel ornamented with bars; the full-faced helmet of steel, with the visor or bevor open, is for baronets and knights; the profile helmet, steel, with the visor closed, for an esquire.

HEMATEIN. [HEMATIN.]

HEMATIN ($C_{32}H_{14}O_{12}+2$ aq.), *hematoxylin*, the colouring-matter of the *Hæmatoxylon campechianum*, or logwood, discovered by Chevreul. It is prepared by evaporating a watery infusion of logwood to dryness, treating the residue with alcohol, filtering the spirituous solution, and evaporating it to the consistence of a syrup. If a certain quantity of water be added to this, and evaporation be performed with a gentle heat, the hematin crystallises, and requires only to be washed with a little alcohol and dried. Hematin crystallises in small laminæ of a reddish colour. The taste of hematin is at first sweet and astringent, and afterwards bitter. It is decomposed by heat. Water dissolves hematin, and the solution is of an orange-red, at 212° Fahr., but becomes yellow on cooling. Acids saturated with oxygen turn its colour first to yellow and afterwards to red; the alkalies in small quantity render hematin purple, and when in excess violet-blue, and eventually decomposing it, make it yellowish-brown. In contact with oxygen and alkalies hematin gives *hematein* ($C_{32}H_{12}O_{12}$), which unites with two equivalents of ammonia, forming a compound of a fine purple colour.

This colouring principle is a constituent part of all the colours prepared with logwood, and the changes which it undergoes by the action of acids and alkalies render it useful as a re-agent to detect their presence.

HEMATOCRYSTALLIN. A red crystalline albuminous matter found in blood under certain circumstances. It is soluble in acetic acid, but insoluble in potash. Ammonia dissolves it with the production of a peach-blossom colour. It contains, according to Lehmann,

Carbon	55·24
Hydrogen	7·12
Nitrogen	17·21
Sulphur	·21

HEMATOIDIN ($C_{14}H_9NO_3$?). A bright orange-red crystalline body formed in blood which has effused into the tissue of a living animal. These crystals are observed from the fourth to the twentieth day after the hæmorrhage. They are insoluble in water, alcohol, ether, and acetic acid, but dissolve in ammonia with a bright red tint, which soon becomes orange-yellow and finally brown.

HEMATOSIN ($C_{44}H_{22}N_3O_6Fe$?), the red colouring-matter of the blood; it has not however been obtained in a perfectly pure state, owing to the difficulty of separating it from other substances, and to the facility with which it undergoes change: when the coagulum of blood, which has been drained, is put into water, the colouring-matter dissolves and forms a fine crimson-coloured solution; this when exposed to a moderate heat dries and forms a brittle dark red substance, which is again soluble in water. When it has been acted upon by heat and alcohol it coagulates, owing to the albumen which it contains, and it is then insoluble in water, but soluble in potash; the red solution is rendered black by carbonic or sulphurous acid, but its colour is heightened by air on account of the oxygen which the latter contains; nitrous oxide renders it purple, and sulphuretted hydrogen greenish-black.

A peculiarity of hematosin is its containing iron, which does not occur in other parts of the animal system: when the clot of blood is decomposed by exposure to heat and air, the residue treated with hydrochloric acid exhibits by the usual tests the presence of peroxide of iron, unaccompanied by phosphoric acid. So also when dried blood is moistened with a little concentrated sulphuric acid, on the addition of water a solution is obtained which with ammonia yields a precipitate of peroxide of iron.

The hematosin of bullocks' blood, but not quite pure, for the reasons already stated, analysed by Mulder, yielded the following ingredients:—

Carbon	66·49	65·91
Azote	10·54	10·54
Hydrogen	5·30	5·37
Oxygen	11·01	11·75
Iron	6·66	6·58
	100·00	100·15

HEMATOXYLIN. [HEMATIN.]

HEMERALOPIA, a word which is now used to signify "night-blindness," though in fact it means "day-seeing," being similarly formed to the genuine Greek word "nyctalopia" (*νυκταλωπία*), which means "night-seeing." Much confusion has arisen in regard to the use of the two words, in consequence of an error committed either by Hippocrates or one of his early editors. In the second book of his 'Prædicta,' he says, "We call those nyctalopes who see by night;" but in the fourth and sixth books of his 'Epidemics,' the disease which he speaks of under a similar term appears to be that in which the patients are blind at night; and his translators, Paulus Ægineta, Ætius, and Galen, quote various authorities to show that those only are properly called nyctalopes who are affected with night-blindness. They have been followed by Bontius, Sir G. Blane, and many naval surgeons, who apply to the present disease the name of nyctalopia, or dysopia tenebrarum. Linnæus and Vogel however define nyctalopia to be night-vision, and call night-blindness, hemeralopia; and as their meanings have been since received by Scarpa, Lawrence, and all the chief writers on diseases of the eyes, they will be adopted here.

Night-blindness is a common disease amongst seamen in the East and West Indies, the Mediterranean, and in all hot countries, and affects in a slighter degree soldiers and the natives in the same parts of the globe. To persons affected by it, all objects appear at sunset as if covered with an ash-coloured veil, which becomes gradually denser, and at last involves them in complete darkness. In slight cases they can see by bright candle-light or by moon-light; but after the disease has lasted a few days, even the largest objects are invisible after sunset, and the patients have to grope their way even where the moon or candles are shining brightly. The disease will daily increase in severity if not judiciously treated, till the sight becomes weak by daylight, and so disordered that total blindness might be apprehended, though it very rarely follows. The pupils are generally dilated, and at night cannot be made to contract even by a brilliant light.

The most probable cause of this disease is the exhaustion of the retina, produced by the continued glare of a bright sun, either directly transmitted to it, or reflected from the clear waters of the tropical seas, or the bright sands of their shores; a condition of which one may form an idea from the inability to perceive objects in a dimly lighted room after leaving one where there was a glare of light. In many cases it is connected with a disordered condition of the digestive organs, and in others with scurvy.

The disease will generally get well, though it may exist for weeks or months. The most successful treatment is the repeated application of small blisters to the temples. Mr. Bampfield cured by this means upwards of 300 cases. This treatment never failed; but in some instances its effects were accelerated by the administration of purgatives and other medicines adapted for the coincident symptoms of scurvy or of disordered digestion. The best description of the disease is in Mr. Bampfield's 'Essay on Hemeralopia,' in the 5th vol. of the 'Medico-Chirurgical Transactions.'

Nyctalopia, night-vision, or day-blindness, probably never occurs as a separate disease. It is often a symptom of scrofulous ophthalmia and other diseases where the eye is so irritable that the stimulus of daylight cannot be borne, as well as of those conditions in which great dilatation of the pupil is requisite for vision, as in commencing cataract, or opacity of the centre of the lens or its capsule.

HEMIO'PIA (from ἡμί, "half," and ὤψ, "the eye") is a disease in which the patient sees only a part of the object he looks at; the middle of it, or its circumference, or its upper or lower part, or more commonly one lateral half, being completely obscured. In some cases it arises from a partial mechanical obstruction to vision, as when part of the transparent tissues of the eye become opaque, or when the upper eyelid falls over half the pupil. But more frequently it is the result of a morbid and partial insensibility of the retina, produced by the excessive stimulus of a bright light, and will cease after a night's rest; sometimes it is a consequence of disordered digestion; and sometimes a symptom of commencing amaurosis, or gutta serena, and terminates in complete blindness.

A very interesting account of this disease is given in the 'Philosophical Transactions,' for 1824, by Dr. Wollaston, who himself suffered from it on two occasions. He endeavoured to explain it by the semi-decussation of the optic nerves [EYE]; and it is remarkable that the appearances found in his brain after death were such as on that theory might have been anticipated. But in a large proportion of the cases the affection is too transient to admit of the supposition of any organic disease.

HEMIPINIC ACID ($C_{20}H_{10}O_{12}+4$ aq.) is formed by the higher oxidisement of opianic acid, one equivalent of which, by the addition of two equivalents of oxygen, gives rise to one equivalent of hemipinic acid; this addition is effected by heating either opianic acid or narcotine with dilute sulphuric acid and binoxide of lead, care being taken not to decompose the hemipinic acid as it is formed.

Hemipinic acid crystallises in colourless quadrilateral prisms. The crystals contain four equivalents of water, which are expelled below 212° Fahr. It has a slight taste, is soluble in water, melts in 356°, and sublimes like benzoic acid in shining laminæ. It is bibasic, and forms with ammonia a readily soluble and crystalline salt; with oxide of silver it forms an insoluble, white, pulverulent powder, the composition of which is represented by $C_{20}H_8O_{10}$, 2AgO.

HEMIPLEGIA. [APOPLEXY.]

HEMISPHERE. [SPHERE.]

HEMITONE, an interval in ancient music, the ratio of which is $\frac{243}{256}$.

HEMP. [LINEN.]

HENDECAGON, a figure of eleven sides. For the regular hendecagon see REGULAR FIGURES.

HEPATITIS. [LIVER, DISEASES OF THE.]

HEPHÆSTUS (Ἥφαιστος) of the Greeks, Vulcánus of the Romans, the god of fire, especially so far as it manifests itself as one of the elementary powers of nature in volcanic districts, and so far as it is an indispensable means for the working in metal and prosecuting the pursuits of industry in general. According to Homer, Hephæstus was the son of Zeus and Hera, and was from his birth so weakly and ugly, that his mother, wishing to get rid of him, dropped him from Olympus. But Thetis and Eurynome, two marine divinities, received him falling, and with them he dwelled concealed for nine years, during which period he made various beautiful ornaments for the two goddesses. Whenever he remembered the cruel act of his mother, he felt indignant at her shameful treatment, and it was in revenge of this act that he made the golden chair, from which, when she sat in it, she was unable to rise, and from which he would not release her until Dionysus interceded for her; but otherwise he was kind and obedient to her, and on one occasion when he took her part against his father, Zeus seized him by the foot and hurled him from Olympus. He fell for a whole day, and came down on the island of Lemnos, where he was kindly received by the Sintians. He afterwards returned to Olympus, where he inhabited a palace built by himself, and which "immortal, starry, brazen," outvied the abodes of the other immortals ('Il.' xviii). Here he had his workshop with its anvil and twenty bellows which worked at his bidding, and he produced the most exquisite specimens of art both for gods and men. His wife is called in the 'Iliad' Charis, but in the 'Odyssey' it is Aphrodite, who however is faithless to him. She favoured Ares, and Hephæstus being informed of it by Helios (the Sun), caught the lovers together in a net, and called all the gods together to witness the spectacle. At the request of Poseidon, however, he liberated them. In the Trojan war Hephæstus sided with the Greeks, though he had a temple and priests at Troy also.

This is an outline of the story of Hephæstus, as far as it can be gathered from the Homeric poems. Other traditions mentioned by later writers state that he had no father, and that he was born of Hera without her having had any connection with a god or male being, in the same manner as Zeus gave birth to Athene. Others called Hephæstus a son of Talus, Coelus, Nilus, or Menanus, but these are foreign traditions transferred into Greece. Some legends describe Hephæstus as having become lame from his fall from Olympus upon the island of Lemnos, whereas according to Homer he was weak and lame from his birth. According to Virgil and other Latin writers, Vulcan does not produce his wonderful works of art alone, but is assisted by the Cyclopes, and his workshop is not in Olympus, but in some volcanic island. His favourite island was Lemnos, but other volcanic islands also, such as Lipara, Hiera, Imbros, and Mount Ætna in Sicily, are described as places in which he lived and worked. The ancient epic poets abound in descriptions of wondrous works of art said to have been made by Hephæstus. Like Athene, he is the divinity that gives skill to mortals, and teaches them the arts which gladden and adorn human life. That both divinities were looked upon as somewhat akin to each other, is clear not only from several legends, but also from the fact that at Athens they had common festivals and temples. The festivals celebrated at Athens in his honour were Hephaestia and Chalcia, the former of which was particularly splendid on account of the torch races (lampadephoria).

The worship of Hephæstus seems to belong to the oldest religious institutions of the ancient world, and undoubtedly arose from the worship of fire, so common among uncivilised nations and in the East. Later poets therefore, in applying the name of Hephæstus or Vulcan to fire in general, returned in some manner to the original idea of the god. In Samothrace, where remnants of the ancient Pelasgian religion continued to exist long after the introduction of the Hellenic religion into Greece, Hephæstus was the first among the Cabiri. In Etruria he was one of the twelve great national gods; and we find his worship established at Rome from the earliest times. A temple of Vulcan, situated close by the Comitium, is mentioned as early as the reign of Romulus and Tatius, and from the stories and rites connected with his worship at Rome, we must infer that his temple was viewed in a similar light to that of Vesta, that is, as a place of union, or the central point of the state.

The Fornacalia (from *fornax*, a furnace), which festival was celebrated at Rome on the 17th of February, was probably an ancient festival of Vulcan; his great festival, however, which was celebrated every year on the 23rd of August, with games in the Circus Flaminius, was in later times the great festival of the god. The Romans often dedicated to him the arms taken from an enemy: they were piled up and burnt. The Romans frequently designate Vulcan by the name Mulciber, which seems to have been given to him as a propitiating name, that he might not destroy the habitations and property of men by fire, but that he might be a beneficent and mild god, using his powers only to serve the human race. Hephæstus was not unfrequently represented in works of art, the most ancient of which seem to have been the dwarfish figures which were placed in private houses near the hearth. When art had reached a maturer state, he was represented as a man of full growth,—at first as of youthful form, later as a bearded and vigorous man. His most celebrated statue was that by Alcamenes at Athens, representing the god in a standing position, and slightly indicating his lameness. On vases and gems he is frequently figured in connection with Aphrodite; as revenging himself on Ares; working in his smithy, &c. His attributes are the instruments of the art of working in metal, as the hammer and the like, the Samothracian oval cap, and the chiton which leaves the right shoulder and arm uncovered.

(Jacobi, *Handwörterbuch der Griechisch. und Röm. Mythologie*, under 'Hephæstus;' Hartung, *Die Religion der Römer*, ii., p. 106, &c.; Hirt, *Mythologisches Bilderbuch*, p. 42, &c.; Müller, *Archäologie der Kunst*, §§ 366-8.)

HEPTAGON, a figure of seven sides. For the regular heptagon, see REGULAR FIGURES.

HEPTYLENE. [ŒNANTHYLENE.]

HERA (Ἥρα) one of the twelve deities of the Greek Olympus, the Juno of the Roman Mythology, was the eldest daughter of Kronos and Rhea, the sister and wife of Zeus, the goddess of marriage and childbirth, and the protectress of married women. Her worship was of very great antiquity at Argos and throughout the whole of the Peloponnesus. The Samians, as well as the Spartans, are supposed to have derived their knowledge of this deity from Argos ('Paus.,' iii. 13; vii. 4); and the same is said to have been the case with the inhabitants of Epidaurus, Ægina, and Byzantium (Müller's 'Dorians,' i., p. 410, Eng. transl.). Her name also occurs in the early mythology of Corinth.

Although inferior in power to Zeus, Hera was treated with equal honour by the other Olympian deities. The Homeric poems contain but little of the mass of strange fiction attached to her in later times. She is represented in the 'Iliad' as jealous, obstinate, quarrelsome, and revengeful. Her disputes with her husband form a subject of frequent reference. At one time she even conspired with Athene and Poseidon to seize and bind the cloud-dispeller, but Thetis gave him warning, and with the aid of Briareus freed him from his bonds. ('Il.' i. 399.) It was then, perhaps, that Zeus inflicted on her the punishment he recals to her memory when angry with her for interfering against Hector and the Trojans; that, namely, of hanging her aloft in the sky, with her hands manacled, and two anvils fastened to her feet. ('Il.,' xv. 17, &c.) Hera seems always afterwards to have had a due dread of openly braving the anger of the father of the gods; but she was not afraid to gain her ends, however opposed to his, by subtlety, of which Homer records several instances. One of the most celebrated of her contrivances was the borrowing the cestus of Aphrodite, in order to stimulate the love of Zeus. ('Il.,' xiv.) But though Homer speaks much of the differences between them, he also shows that Zeus confided his inmost purposes to his wife, and that she always reckons on his confidence. The well-known story of her contention for the prize of beauty with Aphrodite and Athene was told to account for her active interference against the Trojans.

The marriage of Zeus and Hera forms a prominent feature in the worship of this goddess. As a truly married wife, and the wife of the greatest of the gods, Hera became the goddess of marriage and the married state. She was frequently represented veiled as a bride, and carried in processions, like a bride, on a car. By Zeus she had three children, Ares, Hephæstus, and Hebe.

The two most celebrated temples of Hera were at Argos and Samos; the latter was the largest temple with which Herodotus was acquainted. ('Herod.,' iii. 60.) The Samians themselves denied that their knowledge of this deity was derived from Argos, and asserted that she was born in Samos. ('Paus.,' vii. 4.) In many places she was associated in worship with Zeus.

Juno was worshipped at Rome with the epithets *Pronuba*, as presiding over marriage; *Lucina*, as bringing children to the light; *Regina*, as queen of heaven; and *Moneta*, as the warner, to whom a temple was erected on the spot where the house of Manlius Capitolinus stood. ('Liv.,' vii. 28.) The origin of the name *Moneta* is given by Cicero in his 'De Divinatione,' (i. 45). She was also styled *Virginalis* and *Matrona;* and the general festival held on the 1st of March in honour of her, and in which all women took part, was termed Matronalia.

The Greek artists, in accordance with the descriptions of the poets, represented Hera as a fully developed matron, yet as one who bathes in the fountain of virginity; of a perfectly beautiful form and features, but with pride and sternness as well as majesty marked on the countenance. The eyes are large (agreeing with Homer's frequent epithet, "Hera large-eyed, majestic"); the forehead fair and open, and with the braided hair brought down obliquely on either side. She is usually represented with a diadem (stephane), and often wears a veil. Her dress consists of a chiton and himation, the former of which leaves only her neck and arms bare. She often carries a sceptre, sometimes surmounted with a cuckoo; and is accompanied by her favourite bird the peacock. The famous chryselephantine colossal seated statue of Hera, in her temple at the foot of Mount Eubœa, in Argos, of which Polycletus was the sculptor, appears to have served as the type of the goddess for subsequent artists. There are few Greek statues remaining of the goddess of much importance; busts are numerous; we give a cut of a very beautiful one from the British Museum (First Græco-Roman Saloon). Representations of her on vases, gems, &c., are very numerous. The artistic idea of the Roman Juno followed close that of the Greek Hera.

Bust of Hera from the British Museum.

HERACLES (in Latin, *Hercules*), the most celebrated hero of Greek mythology, was the offspring of Zeus by Alcmene, daughter of Electryon, a son of Perseus, and king of Mycenæ. His reputed father was Amphitryon (son of Alcæus, another of the children of Perseus), who having accidentally killed his father-in-law Electryon, was compelled to leave Mycenæ, and take refuge in Thebes. Here Hercules was born and educated, and here his early feats of strength and valour were done; such as slaying the lion of Cithæron, delivering Thebes from the tribute to Erginus, king of Orchomenos, and taking in marriage the daughter of Creon. Most of his adventures were either immediately or remotely the result of the untiring hatred with which he was pursued by Hera. Even his famous twelve labours were the consequence of a sort of compromise entered into with Hera by Zeus, his constant protector, that he should undertake twelve great tasks which Eurystheus, as his master, should think fit to impose, the condition being that if he succeeded in them he should be raised to a place among the immortals in Olympus.

Being thus fated to serve Eurystheus, king of Mycenæ, he performed what are called his labours, in obedience to the commands of his master. They are so well known that we need only enumerate them:—the first was, to bring the skin of the Nemean lion; the second, to destroy the Hydra; the third, to catch the hind of Artemis; the fourth, to bring to Eurystheus the Erymanthian boar alive; the fifth, to cleanse the stables of Augeas; the sixth, to drive away the waterfowl of lake Stymphalis; the seventh, to fetch the Cretan bull; the eighth, to bring to Mycenæ the mares of Diomedes; the ninth, to obtain the girdle of Hippolyta, queen of the Amazons; the tenth, to bring the oxen of Geryon from the island of Erytheia; the eleventh, to bring the apples of the Hesperides; the twelfth, to conduct Cerberus from the under world. Almost innumerable other exploits were performed by him, such as the taking of Troy; the wounding of Hera; the conquest of the gigantes, &c., which are all related by the mythologists, Apollodorus, and others. But we cannot stay to relate them, as our object is rather to point out the classes to which these traditions belong, than to supply information which can be readily and much more suitably obtained elsewhere.

It will be enough to mention the manner of his death. Having to cross the river Euenus, Heracles swam over, leaving his wife to be ferried across by the centaur Nessus. But Nessus faithlessly attempted to ravish Deianeira, and Heracles turning back shot an arrow through his heart. The dying centaur bade Deianeira take some of his blood as a means for preserving the love of her husband. Afterwards when Heracles had been held long entranced with the charms of Omphale, and then leaving her went in quest of Iole, with whom he had become enamoured, Deianeira, fearing the entire loss of his affections, sent him a garment which she had steeped in the blood of Nessus. But the poison from the arrow of Heracles had contaminated the blood, and when the hero put on the garment he was seized with such terrible pains in every part of his body that, unable to bear the agony or to rid himself of the garment which clung to his flesh, he raised a lofty pile of wood on the summit of Mount Œta, and having commanded the shepherd Pœas to set fire to it, he placed himself on the top. Then Zeus caused a cloud to descend from heaven and amidst the pealing thunder, and flashing lightning, the hero was conveyed to Olympus.

There are then three distinct kinds of tradition relating to Heracles; the first consisting of stories drawn from some eastern or other religion, and applied to the Theban hero. Such are his wanderings round the coasts of Greece, which exhibit in a mythical form the establishment of the worship of a wandering god of the Phœnicians. Such also is his voluntary death on Mount Œta; and, according to Müller ('Dorians,' i. 444), his murdering his children. Another, and the second class of traditions, are those which represent him performing labours such as would naturally be those of a young community. (Pausan., viii. 14.) A third class exhibits him in the light of a conqueror and destroyer of tyrants, and here the awkwardness of ascribing the deeds of the Peloponnesian hero to the Theban Heracles is most striking; for while on the one hand he is serving Eurystheus as a slave, on the other he appears as one who forms alliances and disposes of kingdoms.

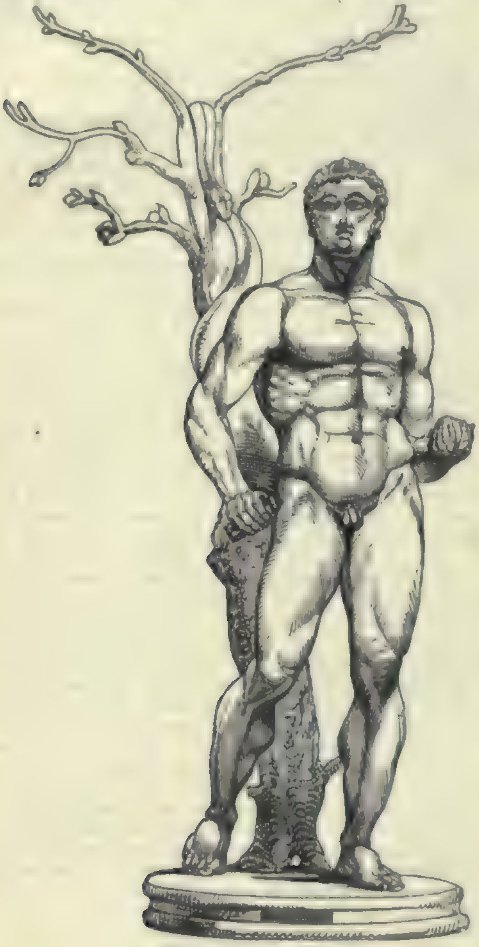
The legends of Heracles perhaps afford a better instance than those of any other hero or god, except Apollo, of the various sources from which mythical accounts spring.

Heracles was worshipped throughout Greece both as a god and a hero. His special oracle was at Bura in Achaia, the seat of the oldest of his temples. Bulls, boars, and rams were sacrificed, and hot springs were sacred to him. Women were not allowed to participate in his worship. At Rome there were two temples dedicated to Hercules.

Representations of Heracles are extremely numerous of almost every period of Greek and Græco-Roman art. In the archaic period the hero was clothed, and armed with spear and buckler, bow or sword; later, his only covering is the skin of the Nemæan lion, his weapon the huge club with which he killed the lion. Always he is figured as of enormous strength, with broad shoulders, large limbs, and muscles extremely developed. His person is noble, his countenance grave and earnest. The famous Farnese Hercules is the most celebrated ancient statue of the hero which has come down to us. It is inscribed with

Bust of Heracles from the British Museum.

the name of Glycon, and appears to be a copy of the Heracles of Lysippus: the hero is leaning on his club, and holds in his hands the apples of the Hesperides; the head of this statue is, however, a modern restoration, being copied from the magnificent colossal head now in the British Museum (Third Græco-Roman Saloon). Besides the many statues and busts of Heracles, in which he is figured from youth to age, there exist representations of him engaged in one or other of almost all the adventures related of him, from his birth to the pyre on Œta, in bronze and marble, groups and relievi; on vases, wall paintings, coins, gems, &c. We give cuts of a small bronze statue and the bust just mentioned; both the originals are in the British Museum. The bronze, which is in all 3 feet 5 inches high, the figure of the hero being 2 feet 6 inches high, was found in 1775, at Jebel, the site of the ancient Byblos, on the coast of Syria; it appears to be of the school of Lysippus, and may possibly be a work of the master himself.



Bronze Statue of Heracles.

The head, which is of colossal size, was dug up from under the lava at the foot of Mount Vesuvius, and presented to the British Museum by Sir William Hamilton.

(Müller's *Dorians*, and the authors whom he quotes; *Prolegomena; Archaölogie der Kunst*, and *Denkmäler der Alten Kunst;* Buttmann's *Mythologus;* and Thirlwall's and Grote's *Histories of Greece.*)

HERACLI'DÆ, the descendants of Heracles. According to tradition, after the death of Heracles his children took refuge in Attica, in order to escape the persecution of Eurystheus. They were hospitably received by Theseus, and with the assistance of the Athenians defeated Eurystheus. After the battle, the Heraclidæ are said to have obtained possession of the whole of Peloponneus; but they had not remained in the country long before a pestilence again drove them back to Attica. They attempted soon afterwards to march again into Peloponnesus, but were met at the Isthmus by an army consisting of Arcadians, Ionians, and Achæans. In a single battle with Echemus, king of Tegea, Hyllus, the eldest son of Heracles, was slain, and the Heraclidæ promised not to invade Peloponneus for a hundred years from that time. (Herod., ix. 26; Pausan., i. 41.) They did not, however, observe their engagement; for both Cleodæus, son of Hyllus, and his grandson Aristomachus, renewed the attempt, but without success. The Heraclidæ retreated to Doris, where they obtained a considerable army to assist them in the recovery of their dominions. With the aid of an Ætolian chief named Oxylus, they crossed from Naupactus to the southern side of the Corinthian Gulf eighty years after the Trojan war. (Thucyd., i. 12.) A battle took place between the Dorians under the command of the sons of Aristomachus and the Peloponnesians under that of Tisamenus, the grandson of Agamemnon, in which the latter were defeated, and all Peloponnesus, except Arcadia and Achæa, fell into the hands of the Heraclidæ. Elis was assigned to Oxylus, and the rest of the Peloponnesus was divided between the three sons of Aristomachus; Temenus obtained possession of Argos, Cresphontes of Messenia, and Aristodemus, or his sons Eurysthenes and Procles (for, according to the general tradition, Aristodemus did not live to enter Peloponnesus), of Lacedæmon. The land of the conquered country was divided among the Dorians, and the old inhabitants were obliged to emigrate, or were reduced to an inferior caste. (Pausan., ii. 18; iii. 1; iv. 3.)

Such is the traditional account of that important event in Grecian history, usually called "the return of the Heraclidæ," by which the Dorians obtained possession of the greater part of the Peloponnesus. It is asserted by the universal tradition of antiquity that the Dorians were led to this conquest by Achæan chiefs; but this fact has been doubted by many modern writers, who have considered it improbable that the Dorians should have been commanded by foreign chiefs. It has been supposed that the Heraclidæ were the hereditary princes of the Doric race, who were descended from a Dorian Heracles; and that the story of the Heraclidæ being descended from the Argive Heracles, who performed the commands of Eurystheus, was not invented till after the conquest of the Peloponnesus. (Muller's 'Dorians,' vol. i., p. 57, Eng. Transl.) Though the general tradition assigned the complete conquest of Peloponnesus to the sons of Aristomachus, it appears probable from other traditions that the greater part of the Peloponnesus was not reduced by the Dorians till long afterwards. (Thirlwall's 'Hist. of Greece,' vol. i.)

HERALD, an officer whose duty, during the middle ages, was to carry challenges or peaceful messages from one sovereign or nobleman to another, to proclaim peace or war, to lay out the lists in jousts or tournaments, to be witness of all combats whether general or particular, and to record in writing the names of those who behaved most valiantly, to number the dead after battle, and specially to supervise all matters connected with the bearing of coat-armour, the marshalling of processions, and other state ceremonies. His functions were something like those of the Greek *kerux* (κήρυξ), and the Roman *Fecialis;* but the origin of the name is much disputed, and the actual date of the institution uncertain. The word *Heraldus* occurs in the imperial constitutions of Frederick Barbarossa, in 1152, about the same time to which the origin of heraldry is with most reason assigned. The earliest mention as yet discovered, of a herald in England is in a pell-roll of the 12th of Edward III.; but there is little doubt that the office existed as early at least as the dawn of hereditary coat-armour. The English heralds were first incorporated by Richard III. [HERALDS' COLLEGE.] There are three orders or grades of heralds, namely, kings of or at arms, heralds, and pursuivants. They were anciently created with much ceremony, and the mode is curiously detailed by Gerard Legh apud Upton. "It is necessary," says he, "that all estates should have couriers as their messengers for the expedition of their business, whose office is to pass and repass on foot, being clad in their prince's colours 'parted upright;' that is to say, half of one colour and half of another, with the arms of their sovereigns painted on the boxes in which they carried their despatches, and which were fixed to their girdle on the left side. It was not permitted to them to bear the arms of their lord in any other manner." "They were knights," he adds, "in their offices, but not nobles, and were called knights-caligate of arms, because they wore 'startuppes' (a sort of boot or gaiter) to the middle leg." "When they had conducted themselves properly in this situation for seven years, they were made chevaliers of arms, and rode on horseback to deliver their sovereign's messages, clad in one colour, their garments being only guarded or trimmed with the colours of their sovereign, and bearing their boxes aforesaid, with the arms painted on them, on the left shoulder, 'and not elsewhere.'" From these runners and riders the three orders of heralds were supplied, the chevalier of arms, having served another seven years, being created a pursuivant in the following manner:—The herald of the province, to whom he was to be pursuivant, wearing his coat of arms, took the candidate by his left hand, holding in his right a cup of silver, filled with wine and water, and leading him to his sovereign, in the presence of many witnesses duly summoned for this purpose, inquired by what name the pursuivant was to be created; and upon the sovereign's answer proclaimed his style accordingly, pouring some of the wine and water upon his bare head. He then invested him with the tabard, or herald's coat, emblazoned with the arms of the sovereign, but so that the sleeves hung upon his breast and back, and the front and hind parts of the tabard over his arms, in which curious fashion he was to wear it till he became a herald. Strutt has given a representation of the pursuivant so attired from the Harleian MS. 2278, without being aware of the distinction. The oath of office was then administered to him, and lastly the sovereign presented him with the silver cup aforesaid. Having once been made pursuivant, he might be created a herald, "even the next day," which was done by the principal herald or king of arms leading him in like manner before the sovereign, but bearing a gilt instead of a silver cup, and turning the tabard so that the sleeves hung in their proper place over the arms.

A collar of SS was then put about his neck, one S being argent, or silver, the other sable, or black, alternately, and when he was named, the prince himself poured the wine and water on his head, and after the oath was administered gave him the cup as before; whereupon the herald cried, "A largess." The kings of arms were created and solemnly crowned by the sovereigns themselves, and distinguished from the heralds by richer tabards, the embroidery being on velvet instead of satin, gilt collars of SS, and coronets composed of a plain circle of gold surmounted by sixteen strawberry leaves, eight of which are higher than the rest.

Modern heralds of all classes in the British dominions are now with some few exceptions, made and appointed by the hereditary earl marshal, and their functions and privileges are much abridged and disregarded. The present number in England is fourteen, namely: four kings of arms—Garter, Clarenceux, Norroy, and Bath; the second and third being provincial kings, Clarenceux having power over all parts of England south of the Trent, and Norroy over all parts north of it. The fourth is specially attached to the Order of the Bath, and is not a member of the College of Arms. Six heralds—Somerset, Chester, Windsor, Richmond, Lancaster, and York; and four pursuivants Rouge Dragon, Portcullis, Blue Mantle, and Rouge Croix. In Scotland there is one king at arms named Lyon; and in Ireland one, named Ulster. There is also a king of arms of the order of St. Michael and St. George in the Ionian Islands. To these regular officers are sometimes added, by command of the king to the earl marshal, a herald or pursuivant extraordinary. Such were the heralds Arundel, Norfolk, and Mowbray; and on the occasion of the funeral of the late King William IV., Mr. Albert Woods, now Lancaster herald, son of Sir W. Woods, then Clarenceux king of arms, was created pursuivant extraordinary.

HERALDS' COLLEGE, or COLLEGE OF ARMS, a corporation founded by Richard III. in the first year of his reign by a charter dated the 2nd of March, 1483, in which he gives to the principal officers of the corporation a house called Colde Arbor, in the parish of All Hallows the Less, London. In the first year of the reign of Henry VII. this house was seized into the king's hands under the Act of Resumption as the personal property of John Writhe, then garter king of arms; and during the reign of that king and of his successor Henry VIII. the heralds made several unsuccessful attempts by petition to obtain a restoration of it, or the grant of some other building for their general use. King Edward VI., in the third year of his reign, by a charter dated June 4th, confirmed to them all their ancient privileges; and Philip and Mary, by charter of the 18th of July, 1554, re-incorporated them, and granted to them Derby House, then occupying the site of the present college on Benet's Hill, near St. Paul's Churchyard. The old building was destroyed in the great fire of London; but all the books, papers, &c., were fortunately saved, and removed to the palace in Westminster, where the heralds held their chapters, &c., until the college was rebuilt. The corporation consists of three kings of arms,—Garter, Clarenceux, and Norroy (Bath not being a member),—six heralds, and four pursuivants. [HERALD.[The arms of the college are—argent, a cross gules between four doves rising azure. Crest, on a ducal coronet, Or, a dove rising azure. Supporters, two lions rampant gardant argent, ducally gorged Or. There is a heralds' college in Scotland, composed of Lyon king of arms, six heralds, and six pursuivants.

HERALDRY, the art of arranging and explaining in proper terms all that appertains to the bearing of coats of arms, badges, and other hereditary or assumed marks of honour; also the science of marshalling processions and conducting the ceremonies of coronations, instalments, creations of peers, funerals, marriages, and all other public solemnities.

The origin of heraldry, in the first and most commonly understood sense, has been attributed by the general consent of all rational writers on the subject, to the necessity for distinguishing by some outward sign, amidst the confusion of battle, the principal leaders during the expeditions for the recovery of the Holy Land. But nothing is absolutely known concerning it beyond the fact that the middle of the 12th century is the earliest period to which the bearing of heraldic devices, properly so called, can be traced, and the commencement of the 13th, the time about which they became hereditary.

The earliest roll of arms of which we have any notice is of the reign of Henry III.; and the reign of Edward I. presents us with the earliest heraldic document extant. The famous roll of Caerlaveroch, a poem in old Norman French, rehearses the names and armorial ensigns of all the barons, knights, &c., who attended Edward I. at the siege of Caerlaveroch Castle in 1300. [BANNER.] Heraldry is therein first presented to us as a science. The principal rules and terms of the art were then in existence, and from about that time the latter are continually found in the fabliaux and romances of France and England.

The oldest writer on heraldry whose work has descended to us is Nicholas Upton, whose treatise 'De Militari Officio' was composed in the reign of Henry V., and translated in that of his successor by Juliana Barnes [BERNERS, in BIOG. DIV.], in the work known as the "Boke of St. Alban's." As Upton quotes no earlier authorities, his definitions and explanations can only be looked upon as assertions made nearly three hundred years after the origin of the practice, and, consequently, to be believed or not, according to the discretion of the reader. In the reign of Richard III. the English heralds were incorporated and the College of Arms founded; and in the following century a swarm of writers arose both in France and England, each contradicting the other, and wasting a world of learning and research in the most absurd and idle controversies.

On the decline of chivalry the study of heraldry became gradually neglected, and the art, which had formed for centuries a portion of the education of princes, and occupied the attention of some of the most learned men in Europe, was abandoned to the coach-painter and the undertaker, while kings of arms and pursuivants were looked upon as mere appendages of state pageantry, their office ridiculed, and their authority defied.

That the pedantic nonsense of such writers as Morgan, Ferne, Mackenzie, &c., contributed to these results, there can be little doubt. A taste for the critical study of antiquities generally is now, however, reviving throughout Europe, and the use of heraldry as a key to history and biography is daily becoming more and more acknowledged.

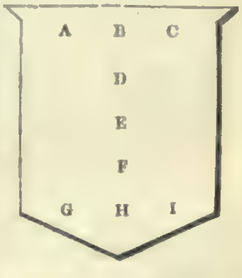
The rules of heraldry, as now practised at the College of Arms, are, as we have before remarked, comparatively modern, and vary in some points from those observed in France and Germany.

According to the received authorities, there are ten classes of arms, namely:—

1. Arms of *Dominion*, being those which sovereigns bear as annexed to the territories they govern.
2. Of *Pretension*, those borne by sovereigns who are not in possession of the dominions to which such arms belong, but who claim or pretend to have a right to such possession; as, for instance, the kings of England from Edward III. to George III. quartered the arms of France.
3. Arms of *Community*, being those of bishoprics, cities, universities, academies, and other bodies corporate.
4. Of *Assumption*, such as are assumed by a man of his proper right without the grant of his sovereign, or of a king at arms; as, for instance, when a man of any degree whatsoever has taken prisoner in lawful war any gentleman, nobleman, or prince, he may bear the arms of that prisoner, and transmit them to his heirs for ever.
5. Arms of *Patronage*, such as governors of provinces, lords of manors, patrons of benefices, &c., add to their family arms, as a token of their superiority, rights, and jurisdiction.
6. Arms of *Succession*, borne by those who inherit certain estates, manors, &c., either by will, entail, or donation.
7. Arms of *Alliance*, such as the issue of heiresses take up to show their maternal descent.
8. Arms of *Adoption*, borne by a stranger in blood, with the special permission of the sovereign, applied for in order to fulfil the will of the testator who may bequeath certain moneys or estates on condition of the party's assuming his name and arms.
9. Arms of *Concession*, augmentations granted by the sovereign of part of his own ensigns or regalia to such persons as he pleases to honour therewith.
10. Arms *Paternal* and *Hereditary*, such as are transmitted from the first possessor to his son, grandson, great-grandson, &c.; thereby forming complete and perfect nobility. The son being a gentleman of second coat-armour, the grandson a gentleman of blood, and the great-grandson a gentleman of ancestry.

These several sorts of arms are displayed on shields, or escutcheons, and on banners, the ground of either being called the field, and the figures borne upon it the ordinaries and charges.

The shield, or escutcheon, contains certain points or locations, namely, A, B, C, the chief: A being the dexter or right-hand chief, B the precise middle chief, and C the sinister or left-hand chief. D is the honour point; E the fess point, being the exact middle of the shield; F the nombril or navel point; G, H, I, the dexter, middle, and sinister base points.



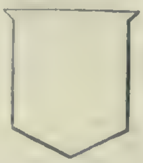
The colours of the escutcheon, or of its ordinaries and charges, are five:—

Red	(the heraldic name of which is) . .	Gules.
Blue	„ „ . . .	Azure.
Black	„ „ . .	Sable.
Green	„ „ . . .	Vert.
Purple	„ „ . .	Purpure.

To which must be added, or rather prefixed, *yellow* and *white*, which being ordinarily represented by gold and silver, are called *metals*, and named by heralds, after the French, *Or* and *Argent*.

There are also two other colours recognised by heralds, but rarely seen in English coats of arms, namely, orange, called *Tenne*, and a dark blood-red inclining to purple, called *Sanguine*, or *Murrey*, from mulberry. These colours and metals have been since the 16th century expressed in engravings by lines and points or dots, the ingenious idea of which is attributed to an Italian named Petrasancta. Thus *Or*, or *gold*, is known by the escutcheon being filled with small points or dots.

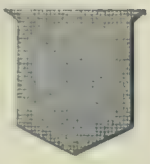
Argent, or *silver*, by the shield being left perfectly plain.



Gules, or *red*, by perpendicular lines from the top to the bottom of the escutcheon.

Azure, or *blue*, by horizontal lines.

Sable, or *black*, by the two former crossing each other.



Vert, or *green*, by diagonal lines from right to left.

Purpure, or *purple*, by similar lines from left to right.

Tenne, or *orange*, by perpendicular lines crossing lines from right to left.

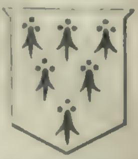
Sanguine, or *murrey*, by transverse lines from each side of the shield.

The metals and colours above mentioned are also distinguished by some heralds by the names of planets and precious stones; and there are besides, according to Sir John Ferne ('Glory of Generosity') twelve other fantastical sorts of blazoning (by which word is meant, describing in proper heraldic terms, the bearings, &c., of a shield or banner); but as all these are now obsolete, we shall only allude to the fact without encumbering our columns by rehearsing them.

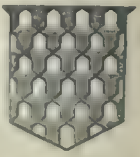
There are nine roundlets, or balls, also used in heraldry, the names of which are sufficient to denote their colour, without particularising the same, namely :—

Bezants .	. Or.	Hurts .	. Azure.	Pellets	. Sable.
Plates .	. Argent.	Pommes	. Vert.	Oranges	. Tenne.
Torteaux	. Gules.	Golpes	. Purple.	Guzes	. Sanguine.

To metals and colours must be added FURS, which, according to some heralds, are of ten different sorts. Those most commonly met with are however comprised under the names of Ermine and Vair, the rest being variations of colour and disposition. The first is represented in heraldry thus, the field being *white*, or *argent*, the spots and tails *black*, or *sable*.



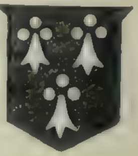
The second is represented by figures like little cups or bells reversed and ranged in lines, thus: the colours being, of the field *Argent*, of the cups *Azure*, or vice versâ; but where the matter is doubtful, the metal to possess the field by pre-eminence.



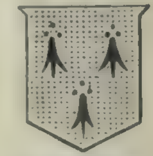
N.B. If the same figures are found in other colours, they are no longer to be blazoned or described as *Vair*; but "*Vairy, Or*, and *Gules*," or whatever else it may be.

The principal variations above mentioned are :—

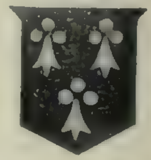
1. *Ermines*, the field of which is *Sable*, and the spots and tails *Argent*.



2. *Erminois*, the field *Or*, the spots and tails *Sable*.

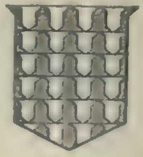


3. Pean, the field *Sable*, the spots and tails *Or*.

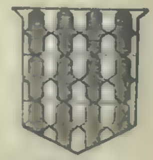


4. *Erminites*, the same as Ermine, with the addition of a *red* hair on each side the *black* tails.

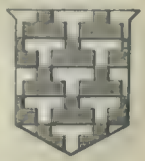
5. *Vair en point* is when the point of a cup or bell is opposite to the base of another.



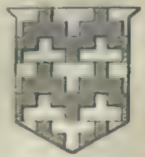
6. *Counter Vair*, when bells of the same colour are placed base to base and point to point.



7. *Potent* is classed as a fur, but the word signifies a crutch or a gibbet (*Potence*, Fr.). It is represented thus—

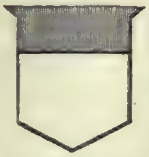


8. *Potent-counter-potent*, sometimes called *Vairy cuppy*, is when the crutches are counter placed; thus—

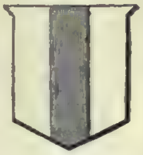


The principal charges or figures expressed on the shield are called the *Ordinaries*; they are nine in number, and styled *honourable*. They consist of the *Chief*, the *Pale*, the *Bend*, the *Bend Sinister*, the *Fess*, the *Bar*, the *Chevron*, the *Cross*, and the *Saltier*.

The *Chief* is the upper third of the escutcheon, determined by a horizontal line; thus—

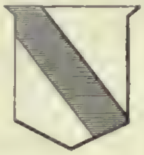


The *Pale* is the middle third of the field when divided perpendicularly.



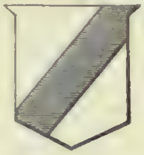
This ordinary has two diminutives; the *Pallet* being half the width of the *Pale*, and the *Endorse* half that of the *Pallet*.

The *Bend* is formed by two diagonal lines drawn from the right or dexter chief to the left or sinister base; thus—

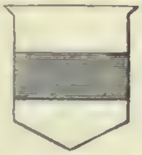


The *Bend* has four diminutives; the *Bendlet*, the *Garter*, the *Cost*, and the *Ribbon*.

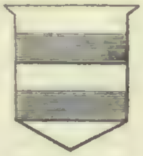
The *Bend Sinister* passes from the left to the right of the shield, and has two diminutives, the *Scarp* and the *Baton*.



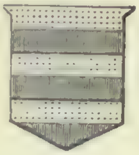
The *Fess* occupies the middle third of the shield divided horizontally.



The *Bar* is similarly formed, but occupies only a fifth of the shield, and is never borne single.

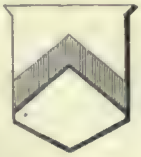


When the number exceeds five, it is blazoned Barry of so many pieces, expressing the number and colour, as Barry of Six, Or, and Gules.

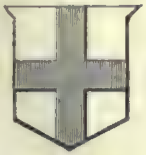


The *Bar* has two diminutives; the *Barrulet*, half the width of the *Bar*; and the *Closet*, half that of the *Barrulet*.

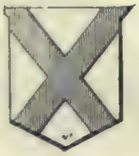
The *Chevron* is a figure formed like the rafters which support the roof of a house, and is therefore sometimes called *a Spar*, and in German *Sparren*. It has two diminutives, the *Chevronel* and the *Couple-close*.



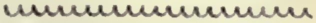
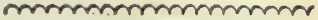
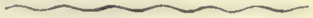
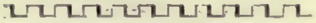
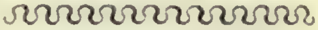
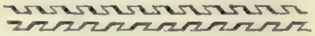
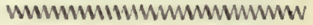
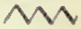
The Cross, as an ordinary, is drawn thus. All other sorts of crosses should, in our opinion, come under the head of common charges, as they must be specially described.



The *Saltier* is *the figure generally* known in England as St. Andrew's Cross, and is indeed always so called by the German heralds, and frequently by the Scotch.



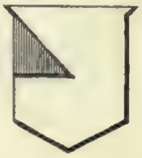
Eight of these nine honourable ordinaries give their names to the various single lines used in dividing the field of the escutcheon, where more than one metal or colour is required, such escutcheon being described as *parted per pale*, when divided perpendicularly; *per fess*, when divided horizontally; *per cross*, when in four squares; *per saltier*, when in four triangles; *per bend*, when diagonally, from right to left; *per bend sinister*, when in the contrary direction; and *per chevron*, when in the shape of that figure. The Chief being itself formed by a single line, they do not say *parted per chief*: but when the partition-line is not straight or even, its peculiarity must be specified in every instance: and of crooked lines there are eight recognised by English heralds, namely :—

1. Engrailed . . .	
2. Invected	
3. Wavy	
4. Embattled	
5. Nebuly	
6. Raguly	
7. Indented	
8. Dancette, limited to three indentations.	

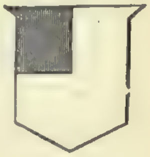
It is therefore necessary to say 'a Chief engrailed,' or 'a Cross invected,' or 'Parted per fess, indented,' and so forth.

In addition to the nine honourable ordinaries are to be mentioned the subordinate ordinaries, the Gyron, the Quarter, the Canton, the Fret, the Pile, the Orle, the Tressure, the Flanches, the Flasques, the Voiders, and, according to some authorities, the Lozenge, the Fusil, the Mascle, and the Rustre.

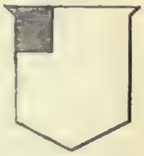
The Gyron is formed thus: and when the shield is divided per cross and per saltier into eight similar divisions, it is called Gyronry.



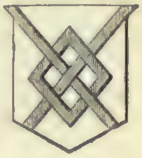
The Quarter is, as its name imports, the fourth part of the shield, and is always placed in chief.



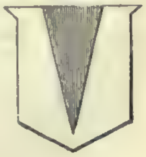
The Canton is a square figure like the quarter, but smaller, occupying only a third part of the chief itself.



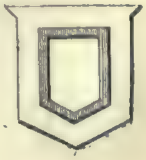
The Fret is formed thus: when composed of more pieces similarly interlaced, the field is said to be *fretty*.



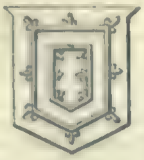
The Pile is formed like a wedge, thus: it is sometimes borne *in bend*, but must then be so described.



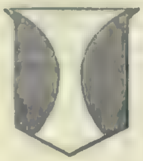
The Orle is a sort of border or frame within the shield.



The Tressure is commonly supposed to be half the breadth of the Orle, and is generally borne double, and what is called fleury and counter-fleury, as in the royal achievement of Scotland.

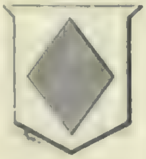


The Flanches are formed by two curved lines nearly meeting in the centre, thus:

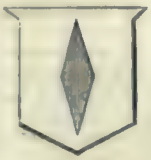


The Flasques may be called the diminutives of the Flanches, and the Voiders the diminutives of the Flasques, as the only difference is in the quantity of the shield which they occupy.

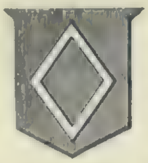
The Lozenge is of the shape of the Diamond in a playing-card. A shield so divided by diagonal lines as to form several of such figures is called Lozengy.



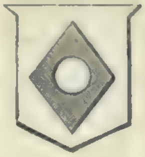
The Fusil, called also a Spindle, is longer and narrower than the Lozenge. A shield so divided by lines as to form several of such figures is called Fusily; and if parted per pale and per bend, would be either Lozengy-bendy or Fusily-bendy, according to the width of the space between the lines.



The Mascle is of the same form as the Lozenge; but hollowed out, or, in heraldic term, *Voided*, so as form a mere frame of that shape.

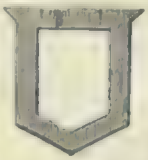


The Rustre is a similar figure, but pierced or voided round, instead of square, thus:



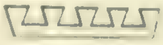
To these some heralds add the Inescutcheon, which is a small shield placed in the centre or top point of the escutcheon; but this, except when borne as an escutcheon of pretence, may, in our opinion, be ranked amongst the common charges, as may also the lozenge, the fusil, the mascle, and the rustre.

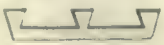
We have next to speak of *differences*, so called from their being particular marks borne to distinguish persons of the same family from one another. While heraldry was arbitrary, the son frequently assumed arms perfectly different from those of his father; but in the time of Edward I. we find two marks generally considered as family differences or signs of cadency,—the *Border* and the *Label*.



The Border is, as its name denotes, a guard or edging to the shield, and by the French heralds is accounted an ordinary. The border should always be in width one-fifth of the breadth of the shield itself, and stops when it encounters a chief, a quarter, or a canton, but passes over all other ordinaries. If the interior line is not plain or even, it must be described as *engrailed*, *invected*, &c. When divided into four equal parts, it is called a *border quarterly*. When divided into small squares of different colours, it is called a border *gobonated*, or *gobony*, or *compony*. When in *two* rows of squares, it is called a *border counter-compony*. When into *three* rows of squares, it is called *checky*.

The Label, or File, as it is sometimes called, is a sort of fillet from which depend generally three or five lambeaux, or points, thus,



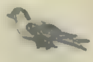


It is sometimes however said to have been borne as a common charge, and is to be found only with one point and with as many as nine: other authorities consider it always as a *difference*. The label of three points is now always used as the difference of the heir or eldest son of the first house.

For the second son the difference is a crescent . .

For the third, a mullet, or star of five points . .

For the fourth, a martlet . . . . . .

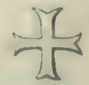


For the fifth, an annulet . . . .

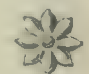
For the sixth, a fleur-de-lys . . . . . .

For the seventh, a rose . . . . . .

For the eighth, a cross moline . . . . . .



For the ninth, a double quaterfoil . . . .



These are called the differences of the first house; and by the six first, the six sons of Thomas Beauchamp, earl of Warwick (temp. Edward III.) are distinguished in a window of St. Mary's Church at Warwick.

The children of the second house are distinguished by the first son bearing a crescent charged with a label: the second, a crescent charged with a crescent; the third, a crescent charged with a martlet, and so on.

The junior branches of the royal family are however distinguished by the label only, the Prince of Wales bearing it simply argent, and the rest differenced by various charges, a practice as ancient as the reign of Richard II.

In the general term *charges* we comprise all descriptions of figures borne in coat-armour, whether things animate or inanimate, real or imaginary, everything in short contained in or placed upon the shield; but those we have above-mentioned are to be distinguished from the *common charges*, by which expressions are understood all other.

Many of these, such as crosses and crosslets in all their variety, escalop shells, bezants (the golden coins of Byzantium, or Constantinople), Saracens' heads, &c., were assumed during the Crusades, or after the return of the Crusaders, by themselves or their families, in commemoration of those expeditions. Others, such as beasts, birds, fishes, reptiles, trees, flowers, the sun, moon, stars, &c., were borne either as types of the peculiar dispositions or qualities, or as denoting by some similarity of sound in the pronunciation the names of the bearers. Such have been called with us *canting* or *punning* arms, and by the French *armes parlantes*. It has been the fashion with modern heralds to decry this species of bearing; to account it of rare occurrence in ancient heraldry, and less honourable where it did occur: but recent investigations prove it to have been one of the most frequent as well as most ancient descriptions of charges, and as worthy of respect as any other. It has indeed been suggested that the bearing frequently gave rise to the surname itself. This is however a mere conjecture; but the grants of arms which have been handed down to us prove incontestably that when sovereigns desired to express their approbation of noble or useful deeds by such distinctions, the name of the person to be honoured was frequently expressed by the charge, instead of the act he had performed, which would never have been the case had it been considered in those days as an inferior bearing. An acquaintance also with the language of the nation and time in which the arms were first granted or assumed, as also of its pronunciation, is of the greatest importance to this question, and such researches may yet shed much light upon the origin and history of heraldry. The Cornish family of Godolphin bear a white eagle; but those who are unacquainted with the ancient Cornish language would be far from guessing that a white eagle was called in that language, *Godolcan*, a very near approach to the name of the bearer. A third species of allusive bearings is that which designates the place or office of the individual; and many charges appear in the arms of our nobility derived from ancestors who have held situations of high honour or great trust under our early monarchs; and lastly, a fourth portion have been assumed, as Camden has exemplified, in honour of the feudal lord, or most powerful neighbouring chief, or been conceded to the bearer by such nobleman as a mark of respect or affection.

The crest is the next object in point of antiquity to the shield. It was the ornament worn upon the helmet, and consequently the helmet itself was generally represented with it upon the seal of the knight or nobleman. The crest from Richard II.'s time was rarely worn, except upon the tilting helmet, and then upon a wreath which was generally a twisted roll of silk of two colours, being those of the family of the wearer. Beneath this wreath was frequently worn, as a sort of hood to the helmet, a piece of silk or velvet lined with ermine, which floated with jagged ends on the shoulders: these are by the French called *hachemens*, and by us *mantlings* or *lambrequins*. *Supporters* are of later origin, and are supposed to have taken their rise from the fanciful devices of the early seal-engravers, who filled up the space not occupied by the shield with all sorts of monsters or natural animals, by way of ornament. They did not become common till the close of the fourteenth century, and Henry VIII. was the first monarch who formally granted supporters to peers of the realm and knights of the garter and of the bath. No person under the rank of a knight of the bath has a right to supporters, unless by special grant of the sovereign.

Mottoes had their origin probably in the war-cries of the different knights. There are several instances however of a motto being borne in addition to the *cri de guerre*.

The badge or device is frequently confounded with the crest; but it was altogether independent of the armorial bearings of the family, although in many instances it became hereditary. It is frequently, but very incorrectly, placed upon a wreath.

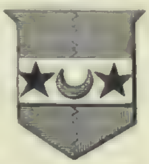
The arrangement and description of all the above insignia in proper heraldic order and terms are styled the *marshalling* and *blazoning* of arms.

We shall speak first of *blazoning*. The verb "to blazon" is generally derived from the German *blasen*, to blow or sound a horn or trumpet, such being usually the practice before proclaiming the style or arms of any personage on his arrival in the camp, the lists, or the banqueting hall. The term however was soon applied to the proclamation itself, and finally used as synonymous with description generally: thus we find in the old book on hunting written by Jacques de Fouilloux, and presented to Charles IX. of France, the description of the hare entitled 'Le Blason du Lièvre.' To spread the fame or the disgrace of any person was also to blazon it. Favine, in his 'Théâtre d'Honneur,' says, "Les habitans disent pour blasonner leur ville;" and in the Chronicle of Louis I., duke of Bourbon, the knights of the order of the crown are commanded not to suffer any person to defame (blazonner et medire) the ladies.

The principal rules of blazoning are as follows:—

1. In blazoning a coat the herald begins with the field, noticing the lines, if any, by which it is divided, the difference of those lines, and then the colours, next the charges, beginning with the *immediate* charge, that is, the one which lieth nearest the field, such as any ordinary, and nearest the centre of the field if a common charge, and lastly, the more remote or inferior charges.

Thus the accompanying coat would be blazoned: *Party per pale, indented, azure, and gules; on a fess argent, a crescent of the first between two mullets sable.*



2. All tautology is to be strictly avoided, and the repetition particularly of such words as *of*, *or*, and *with*, is considered a great fault. In the above blazon, "a crescent of the *first*" is said, in order to avoid the repetition of the word *azure*; so, if it were gules, we should say "a crescent of *the second*." For the same reason, when the field is undivided, and the charges, though of more than one description, of only one colour or metal, it would be blazoned in this way: "Argent, a chevron between three mullets sable," by which the chevron is understood to be sable as well as the mullets.

3. It is accounted by English heralds false heraldry to put metal upon metal, or colour upon colour; but instances of such blazoning frequently occur in foreign arms, particularly in those of German families. The objection is notwithstanding a sound one, as the charges should be rendered as distinct as possible, which can only be done by adhering to the English rule.

4. When a charge is represented of its *natural* colour, it is to be blazoned *proper*.

5. In blazoning animals, the teeth and claws, or talons, of the ravenous beasts are called their arms; and when they are to be represented of a different colour or metal from that of their bodies, they must be blazoned as "*armed*, Or," or "Gules," as the case may be. If the tongue is shown the beast is said to be langued of such or such a colour, as "a Lion, argent, *armed* and *langued*, azure." More docile animals, the stag and deer, for instance, are said to be "attired," and not "armed." Beasts of prey are, according to their attitude, blazoned, *Rampant*, *Rampant-guardant*, *Rampant-regardant*, *statant*, *passant*, *salient*, *sejant*, *couchant*, *dormant*, *naissant*, *issuant*, *combattant*, *endorsed*, *erased*, &c. Stags are said to be *trippant*, *at gaze*, &c.

Birds of prey are also blazoned as "armed" of such a colour, but such as have no talons are described as "beaked and membered." *The Cock* is said to be *armed*, *crested*, and *jelloped*, the latter term referring to the wattles, or gills.

Birds, according to their attitudes, are blazoned *Volant*, *Displayed*, *Preying*, &c.

Fish, when placed horizontally, are termed "*naiant*;" when perpendicularly, "*hauriant*;" when *bent* (as the dolphin is generally represented), "*embowed*;" if face to face, "*respecting each other*;" if back to back, "*endorsed*."

The sun must be blazoned according to his condition, full, or in his eclipse. The moon, defined as crescent, *in*crescent, or *de*crescent: the first being, when represented with the horns upwards; the second, when the horns point to the dexter or right side of the shield; and the third, when to the left or sinister side. If downwards, it is called a *crescent reversed*.

The human figure is blazoned either *vested* or *naked*. Parts of the human figure, if cut off, are said to be *couped*; if ragged or torn off, *erased*. Heads are also blazoned *wreathed* or *banded*, as the case may be.

Flowers are blazoned *jessant*, *slipped*, *seeded*, &c.

When the field of an escutcheon is covered with flowers of the same colour or metal, or any other pattern with flowers or scroll work intermixed, it is said to be *diapered*; but when it is filled with flowers, crosses, or any other device of another colour or metal, repeated, as the French say, *sans nombre*, it is then blazoned as *semée*. An animal so covered with flowers or crosses should be blazoned as *powdered*. When the field, charge, or supporter is covered with *goutes*, or *drops*, it is called *gutty*; and if of gold or yellow, *gutty d'or*; of argent *gutty d'eau*; of gules, *gutty de sang*; of azure, *gutty de larmes*; of vert, *gutty de vert*; and of sable, *gutty de poix*. When a bend, fess, or any other ordinary passes over an animal, the animal is said to be *debruised*. When the charge is divided by any of the partition lines, and the colours of the field are reversed upon it, it is said to be *counterchanged*.

By *marshalling* of arms we understand the orderly disposition of sundry coats, belonging to distinct families, in their proper places within one shield, by impaling or quartering; and the joining of ensigns of honour and dominion with the paternal arms of the bearer, &c.

When a man marries he impales his wife's paternal arms, by placing them upright on the left side of his own in the same escutcheon, such impalement being also called *arms en baron et femme*. If that wife should be or become an heiress, the husband may bear her arms on an escutcheon of pretence over his own; Legh says, however, that this should not be done till he has begotten an heir of that heiress. In Scotland the husband frequently quarters the arms of his wife with his own when she is an heiress. In England this is only done by the children of such a marriage. If the mother be no heiress, the children cannot quarter her coat.

Another mode of impalement was by taking only half of each coat, and joining them in one escutcheon. This was called *dimidiation*; but the practice has long fallen into disuse.

The complete escutcheon of a family should never, according to some authorities, consist of more than six or eight quarterings; others admit of sixteen; and the Germans marshal sometimes twenty and thirty coats in one shield.

The best mode of marshalling so many is to begin by placing the arms of the first heiress who married into the family next to the paternal coat, and next to them the several coats which that heiress brought in; then the arms of the second heiress, followed by those which she brought in, and so on in rotation. When the royal arms are brought in by any match, it is usual however to give that match the second quarter next to the paternal coat, and some say it should even take precedence of that.

The arms of a widow are composed of her husband's and her father's impaled within a lozenge.

Those of a maid are her father's only, borne in a lozenge also, without any difference, except she be of the royal family, in which case a distinction is expressly furnished by the heralds for the individual coat by the command of the sovereign.

If the widow be an heiress, she may wear her paternal coat in an escutcheon of pretence over that of her husband, the latter however being in a lozenge, and her daughter, while unmarried, may quarter her mother's arms with her father's in a lozenge; but if the mother be no heiress, then, says Legh, the daughter has no further right to the arms of her mother's family, except to set them up pale-ways in her house to show her descent.

If the husband be a knight of the garter, or of any other order, the arms of the wife must not be impaled, but placed in a separate shield.

Such are the principal rules and terms of the science of heraldry: for further detail we must refer our readers to the works of Edmonson, Nisbett, Berry, &c., cautioning them, at the same time, against the Scylla and Charybdis of the heraldic inquirer, the absurd and misdirected enthusiasm of the champions of the art, and the undeserved contempt of its depreciators. By the latter it has been stigmatised as "the science of fools with long memories." It should rather be designated as a science which, properly directed, would make fools wise. It is, we repeat, a key to history which may yet unlock stores of information; at present its most learned professors have studied the art itself more than the use which may be made of it. They have wasted their time and their learning upon idle controversies, and still more idle speculations. A mysterious signification has been given to nearly every charge and tincture known in armoury, and a different one by nearly every writer upon the subject. The names of the ordinaries and colours have been derived from every sort of object and through every known language, without one fact having been elucidated on which we can depend. Even the word *blazon*, the only one we have ventured to hint the origin of, has been hotly claimed as Arabic by some disputants, and we will certainly not extend this article one line by an attempt to disprove it.

HERCULES, one of the old constellations, called *ἐγγόνασιν* by Aratus, Hyginus, and Ptolemy, and described by the first as "a figure like that of a man in sorrow" while the second offers various fabular significations from the stories of Hercules, Orpheus, Cetheus, Theseus, Thamyris, Ixion, Prometheus, &c. The club, lion's skin, and character of Hercules, are not so old as Aratus, who describes this figure as stretching his hands to different quarters, and makes an allusion to the neighbouring dragon, which shows that he was not painting a hero.

The constellation is situated between Draco, and Bootes, Lyra, and Ophiuchus; but as there is no star in it larger than of the third magnitude, there is nothing very remarkable about it. The stars α and β lie between the bright stars in the head of Ophiuchus and in Corona Borealis. The following is a list of the principal stars:—

Character.	No. in Catalogue of Flamsteed.	No. in Catalogue of British Association.	Magnitude.
γ	20	5466	3·5
τ	22	5463	4
β	27	5525	2·5
η	28	5531	4
λ	29	5532	4
σ	35	5552	4
ζ	40	5604	3
η	44	5617	3
ε	58	5731	3
α	64	5821	3·5
δ	65	5828	4
π	67	5834	3·5
ρ	75	5886	4
ι	85	5990	4
μ	86	6021	4
θ	91	6082	4
ξ	92	6084	4
ο	103	6150	4
. .	109	6251	4

HERCULES. [Heracles.]

HEREDITAMENT. [Chattels; Descent; Estate.]

HERESY, HERETICS. The word "heresy" (from *αἵρεσις, choice*) was originally used to express any opinion which a man adopted. Thus it was applied to the philosophic sects of Greece and Rome. (Cicero, 'Paradox. Proœm.') In the New Testament the term often simply denotes a religious party, without implying any censure. (Acts, v. 17; xv. 5; xxvi. 5; xxviii. 22.) Josephus calls the three great Jewish sects "*heresies*." ('Antiq. Jud.,' xiii., c. 5, s. 9.) But it is also used in the New Testament as a term of reproach. Thus it was applied by the Jews to Christianity (Acts, xxiv. 5, 14), and by the Apostles to those who resisted their doctrines (1 Cor., xi. 9; Gal., v. 20; 2 Pet. ii. 1; Tit., iii. 10). The fathers applied the words *heresy* and *heretics* respectively to opinions which were different from what they considered the doctrine of the Apostles, and to those who held such opinions, though some of the fathers draw a distinction between *heresy* as a wilful rejection of the doctrines of Scripture, and errors arising from ignorance or weak judgment. When the creed of the church began to be settled by ecclesiastical councils, all who refused to submit to their decisions were denounced as heretics. They were also called *heterodox*, while those who adhered to the opinions of the church were called *orthodox*, or *catholic*. Heretics were distinguished from unbelievers, inasmuch as they professed Christianity. Heresy must not be confounded with schism: the former relates to doctrine; the latter is any division on points of discipline. The number of heresies mentioned by early ecclesiastical writers is from 80 to 150; but Lardner ('Hist. of Heretics,' i. 5) has shown that many of these ought to be excluded from the list; nor have we any evidence that many of them had numerous followers.

Most of the heresies of the first two centuries related to the creation of the world, the origin of evil, the person of Christ, and the connection between Judaism and Christianity; and nearly all may be included under two great sects:—1. The Ebionites and Nazarenes, who, upon embracing Christianity, adhered to many Jewish opinions and ceremonies. 2. The Gnostics, who engrafted upon the Christian religion certain opinions of the Greek and Oriental philosophy. Some however regard the Ebionites as a sect of Gnostics. Both these heresies are supposed to have commenced in the Apostolic age, and to be referred to in the writings of St. Paul and St. John. [Ebionites; Gnostics.]

The Gnostics appear to have been very early divided among themselves concerning the respect which ought to be paid to the Mosaic law, and a new sect was formed by a Jewish Gnostic named Cerinthus [Cerinthus, in Biog. Div.] The Nicolaitans mentioned in the 'Apocalypse' (ii. 6, 15) are supposed to have been a sect of Gnostics, and some identify them with the Cerinthians. About A.D. 121, Valentinus, an Egyptian, engrafted some opinions of his own upon Gnosticism, and founded a new sect. His party was strongly opposed by Irenæus and Tertullian. Another sect which took its rise from the opinions of the Gnostics was that of Cerdo and the more celebrated Marcion, who began to propagate their tenets at Rome about A.D. 130. The principal feature of this heresy was the adoption of the Oriental belief in two supreme powers, the one good and the other evil. The principal followers of Marcion were Lucian, or Leucius, and Apelles. About A.D. 172, Bardesanes and Tatian gave rise to a new sect of Gnostics, which was chiefly distinguished by the practice of an austere discipline. These people were called, from their habits of abstinence, Encratites, Hydroparastates, and Apotactites. The Docetæ were a sect of Gnostics who sprung up very early. They held that the body of Christ was immaterial, and therefore did not suffer on the cross, but only appeared to die. Several minor sects of Gnostics are mentioned by ancient writers, such as the Adamites, the Cainites, the Sethians, and the Ophians, an account of which is given in Lardner's 'History of Heretics.' Lardner doubts the existence of such sects as the Adamites and Cainites. The sect of Eclectics, or New Platonists, was founded at Alexandria in the 2nd century; but though its tenets were embraced by many Christians, it is rather to be regarded as a philosophical than a Christian sect. [Eclectics.]

We now come to the heresies which existed from a very early age respecting the divinity of Christ. This doctrine was denied by some of the Ebionites in the 2nd century. [Ebionites.] About the end of that century Praxeas founded a new sect. Denying the doctrine of the Trinity, he held that the divine nature was intimately united with the person of Christ, whom he considered to be a mere man, but born of a virgin. His followers were called Monarchists, from their rejecting the doctrine of the Trinity; and Patripassians, because they were supposed to believe that the Father suffered on the cross: this opinion however they seem to have disclaimed. In the opinions of Praxeas ecclesiastical historians trace the germ of the Sabellian heresy. His chief antagonist was Tertullian. His opinions were held, with some slight variations, by his contemporaries Artemon and Theodotus. Among the heresies of this age respecting the creation of the world was that of Hermogenes, who believed in the eternity of matter.

The Montanists, who arose in Phrygia about the year 170 (some say 150), are rather to be looked upon as fanatics than heretics. Their leader Montanus claimed the character of a prophet: he appears to have differed from the orthodox in no leading doctrine, but only in some points of discipline. His opinions owe their celebrity chiefly perhaps to the circumstance that they were embraced by Tertullian. [Tertullian, in Biog. Div.] We find traces of this heresy down to the time of Augustine and Jerome. Some inconsiderable heresie arose in the 2nd century on points connected with the rites and ceremonies of the church, such as the Artotyrites and others, [Communion.]

In the 3rd century Gnosticism still had adherents, though it was fast falling into disrepute. But a new heresy arose out of the Oriental philosophy, headed by Manes, who attempted to unite the doctrines of the Persian Magi with those of the Apostles. [Manichæans.] The controversy on the Trinity and the person of Christ continued with increasing warmth. About the middle of the century the doctrines of Praxeas were revived, with slight variations, by Noëtus of Smyrna, Sabellius, an African bishop, and Beryllus, an Arabian. The last two were opposed by Dionysius of Alexandria and Origen. [Sabellius, in Biog. Div.] Another heresy relating to the same subject was established by Paul of Samosata, bishop of Antioch. A new sect of Ebionites, or Jewish Christians, appeared about the middle of the 3rd century, but it lasted only for a short time. They were called Elcesaites, from their founder Elxai. The Novatians, followers of Novatian, a presbyter of Rome, are reckoned, perhaps erroneously, among the heretics of this century. They held no doctrines different from those of the Catholic church, but maintained a greater severity of discipline; and hence they were called Puritans (*καθαροί*). By some historians they are regarded as austere and turbulent fanatics, while others rank them as the earliest sect of reformers in church discipline.

In the 4th century the attention of the church was chiefly occupied with the Arian controversy. [Arius, in Biog. Div.] Out of these disputes other heresies arose respecting the person of Christ, such as that of Apollinaris [Apollinaris, in Biog. Div.], Marcellus, Photinus, and Macedonius. Near the end of this century we find a new sect of Gnostics in Spain, under the name of Priscillianists. The Donatists, who caused great commotions in the church during this century, are rather to be classed as schismatics than with heretics. [Donatus, in Biog. Div.] For an account of certain minor sects in the 4th century, see Epiphanius, 'De Hæresiis.'

At the beginning of the 5th century the Pelagian controversy arose. [Pelagius, in Biog. Div.] The disputes concerning the Trinity and the person of Christ continued to give rise to new sects, the chief of which were the Nestorians and their opponents the Eutychians, or Monophysites. [Eutyches, in Biog. Div.] The controversies of these sects with the orthodox and each other continued nearly 200 years, producing various minor sects, such as the Monothelites, the

Anthropomorphites (who maintained, from Genesis, i. 27, that God had a human shape), and others.

The rapid spread of the monastic system in this century was warmly resisted by Vigilantius, who thus incurred the enmity of Jerome, and has been ranked among the heretics.

In the 6th century the Monophysites continued to branch out into new sects, several of which arose on the question whether the body of Christ was corruptible or incorruptible. Other minor sects are mentioned by Mosheim. ('Ecc. Hist.' vol. ii.) After this time most of the ancient sects remained in existence in different parts of the Christian world with greater or less vigour. The only new sect which requires a distinct notice is that of the Paulicians, which was formed in Armenia and Cappadocia in the 7th century. After suffering severe persecutions they were dispersed over Europe, in various parts of which they formed settlements about the 11th century. The origin of the Albigenses is traced to a body of Paulicians which settled in France. [ALBIGENSES.] The doctrines of the Paulicians have been identified by some with those of the Manichæans, while others regard them as reformers of the corruptions of the church. (Vaughan's 'Life of Wycliffe,' Introd., c. ii.)

Before the Reformation in England heresy was the holding of opinions contrary to the Catholic faith and the determination of Holy Church (2 Hen. IV. c. 15). The court in which a man could be convicted of heresy at common law, was that of the archbishop in a provincial synod. After conviction the criminal was delivered up to the king to do what he pleased with him. If the criminal had abjured his heresy and then relapsed, the king in council, upon a second conviction, might issue the writ De Hæretico comburendo, upon which the criminal was burnt alive. One Sawtre, it is said, was the first man burnt alive for heresy in England, and the writ De Hæretico comburendo was formed in this case. But the above-mentioned statute empowered the diocesan alone, without a synod, to commit a man for heretical opinions, and to imprison him as long as he chose, or fine him; or if he refused to abjure, or after abjuration relapsed, the sheriff, mayor, or other officer, who should be present, if required, with the ordinary or his commissary, when the sentence was pronounced, was to take the convict and burn him openly, without waiting for the king's writ.

It is unnecessary to mention the statutes of Henry VIII. relating to heresy. The Reformation was not fully established till the reign of Elizabeth, the first statute of whose reign repeals all the former enactments, and leaves heresy as it stood at common law. (5 Rep. 23). There is no statute that determines what heresy is. The statute of Elizabeth limited it to 'such as heretofore hath been adjudged heresy' by the authority of the Scripture or the first four councils. After the Reformation was fully established, heresy was punished by ecclesiastical censures, and by burning alive a criminal who had been convicted in a provincial synod. The writ for burning the heretic could not be demanded as a matter of right, being left to the discretion of the crown; but both Elizabeth and James I., in their discretion, thought proper to grant the writ. Elizabeth, it is said, burnt alive two anabaptists, and James two Arians.

The statute 29 Charles II. c. 9, abolished the writ De Hæretico comburendo; and heresy is now left entirely to the ecclesiastical courts. As Elizabeth and James practically showed their approbation of burning heretics alive, so Lord Coke (3 'Instit.' c. 5) approves of the punishment.

At present the ecclesiastical courts punish for heresy, when they do punish, *pro salute animae*, as it is termed—that is, solely out of regard to the soul of the offender. But it is difficult to say at present what can be called heresy; and perhaps it is difficult to say what is exactly the punishment for it.

Its history in England is instructive, but the change from burning alive to the free expression of opinion on religious matters is one of the greatest steps in the social progress of this country. For some other matters connected with the subject, see BLASPHEMY. (Blackst. 'Comm.' Mr. Kerr's ed., vol. iv. p. 40.)

HERIOT is a feudal service consisting in a chattel rendered to the lord on the death of a tenant, and in some places upon alienation of a tenant. It is stated to have originated in a voluntary gift made by the dying tenant to his lord and chieftain of his horse and armour. (Glanvile.) This render became first usual, then compulsory; and at an early period we find the ancient military gift sinking into the render of the best animal (at the election of the lord) possessed by the tenant, and sometimes a dead chattel, or a commutation in money. (Bracton, Fleta; Coke-Littleton.)

Heriots are either heriots-custom or heriots-service. Where a heriot is due from the dying tenant by reason of his filling the *character* or *relation of tenant* within a particular seigniory, honour, manor, or other district, in which it has been usual from time immemorial to make such renders upon death or alienation, it is called *heriot-custom*: *heriot-service* is a heriot due in respect of the *estate* of the tenant in the particular land held by him.

For heriot-custom the lord cannot distrain, because the duty arises out of the character or relation of tenant sustained by the party within the seigniory, &c., in which the custom is found to exist, and not, as in the case of heriot-service, in respect of the particular land holden. As the selection of the best animal is however with the lord, he may determine his choice by an actual seizure, upon which the property in the animal will vest in the lord by the mere act of seizing it.

But for heriot-service the lord may either seize or distrain. He may seize, because by this act of selection the property is vested in him; or he may distrain, because, the land being the debtor, the lord may, by the coercion of a distress upon that land, compel the succeeding tenant to deliver or procure the delivery of the heriot.

Where the heriot-service has been created since the time of legal memory, it is called a *heriot by reservation*, and sometimes a *suit-heriot*: if its origin go back beyond the limits of legal memory, it is called a *heriot by tenure*.

Heriot-custom formerly prevailed very extensively in freehold lands, but is now more commonly found in lands of customary tenure, whether copyholds,—the conventionary estates in Cornwall, held under the duke of Cornwall,—the customary estates called *customary freeholds* in the northern border counties,—or lands in ancient demesne.

Heriot-service may be reserved in respect of a freehold, or leasehold, or a customary tenure; but as, since the statutes of Quia Emptores and Prerogativâ Regis, it is probable that no new sub-tenures in fee have been created, and as it has not been usual to reserve heriots upon gifts in tail, or upon the creation of freehold leases for lives, heriot-service in modern times is generally found in connection with long leasehold estates, where, in consequence of some restriction imposed upon the exercise of the leasing power, or in token of respect for ancient usages, this species of render has been retained.

Heriots, whether heriots-service or heriots-custom, are multiplied whenever the land subject thereto becomes divided amongst different tenants holding distinct parts of such lands in severalty. Where therefore land is held subject to a heriot-service to be rendered at the death of a tenant, if the tenant alien part of the land a distinct heriot will be due upon the death of both the alienor and the alienee; and if such distinct heriots have in fact become due and have been rendered or compounded for during the alienation (whereby the lord will have obtained actual seisin of the several heriots), the liability to pay such multiplied heriots will continue, even though all the land should afterwards be reunited, and vest again in the same person. Inattention to these rules has caused some strange and contradictory decisions in the courts of Westminster. (2 Nevile and Mann, 798.)

A distress for heriot-service must be taken upon the land in respect of the tenure or upon the demise of which it is reserved; and where double or treble heriot has become payable by reason of alienation, the liability attaches severally upon each of the severed portions of the estate. All goods found upon the land, except such as are privileged from distress [DISTRESS], may be taken as a distress for a heriot-service, whether they belong to the tenant or to a stranger, such goods being held merely as a pledge for the performance of the service. But where a heriot-service is by the terms of the reservation commuted for a money payment (or rather, where the reservation of a contingent money payment is improperly designated a heriot), the reservation will be in substance a rent; and therefore the distress taken for this reservation (so miscalled a heriot), if not redeemed by payment, or replevied within five days after notice, may be sold as a distress for rent under the provisions of 2 William and Mary, c. 5.

Heriots were known in England before the complete development of the feudal system which followed upon the Norman conquest. The Normans introduced reliefs [RELIEF] without abolishing the analogous heriot. The *heregeate* (heriot) is mentioned and fixed by the laws of Canute, 67, &c. The Dano-Saxon 'heregeat' is derived by Spelman, and after him by Wilkins, from *herge* (more properly *here*), army. It means literally, "war-treasure," a contribution given to the lord to enable him to carry on war. Originally it seems to have been a poetical expression for the horse and armour which as before mentioned were the chattels given in the earliest times by way of heriot. In Scotland, where the render upon the death of the tenant is a pecuniary payment, it is called "lord's money," "hergeld," or "herrezeld."

HERMÆ, terminal or pillar statues, placed in Greece and Rome at the meeting of streets and roads, in front of houses, temples, and other public places. They were termed Hermæ from the head being usually that of Hermes. The pillar on which the head was placed was mostly quadrangular, the whole being the height of a man. Several of these Hermæ are in the British Museum. [TERMINUS.]

HERMES, one of the twelve Olympian deities of the ancient Greeks, known to the Romans as *Mercurius*. According to Hesiod ('Theog.,' 942), he was the son of Zeus and Maia, the daughter of Atlas. The attributes of this deity are numerous and of opposite kinds; but it appears probable that he was originally considered to preside over flocks and herds. Hesiod says ('Theog.,' 441) that the shepherds address their prayers to him; for which reason the statues of Hermes are frequently represented with a ram by his side or on his shoulders. ('Pausan.,' ii. 3, 4; v. 27, 5; ix. 22, 2. See also 'Iliad,' xix. 490-1.) The phallic form, which distinguished the Hermæ at Athens ('Herod.,' ii. 51), also appears to indicate that this god was considered to increase the fruitfulness of the fields and cattle. Herodotus informs us (ii. 51) that the Athenians were taught by the Pelasgians this manner of representing the statues of Hermes; and that the reasons for this custom are explained in the Samothracian mysteries. Hermes was represented in a similar manner at Cyllene in Elis. ('Pausan.', vi. 26, 3.) This custom is also spoken of by Cicero ('De Nat. Deor.', iii. 22) and

Macrobius ('Saturn.', i. 19). According to some traditions, Hermes is said to have been born in Arcadia ('Pausan.', viii. 16, 1), and to have been the father of Pan; but according to another tradition, he was born at Tanagra in Bœotia. ('Pausan.', ix. 20, 3.) He was worshipped by the Thessalians above all other deities. ('Herod.', v. 7.)

In Homer the name of this deity is usually Hermeias. He is represented as the messenger of Zeus and the gods, and he conducts the souls of the departed to Hades. In later times he was regarded as the god of eloquence; but this no doubt arose from the association of skill of speech with the herald's office. As god of eloquence tongues of animals were offered to him. Hermes was the inventor of the alphabet; of numbers; of music, and of musical instruments, as the lyre and the syrinx; also of weights and measures, and various other things. He was the patron of merchants and of gain, and even of thieving—of all things in fact the exercise of which required prudence, cunning, and dexterity. And he was the protector of travellers, heralds, poets, musicians, and of those engaged in gymnastic exercises.

All the accounts from Homer downwards, unite in attributing to him extreme acuteness, and a propensity for thieving. One of his very earliest deeds, according to some writers within a few hours of his birth, was to steal the oxen of Apollo, from Pieiria, though others place it at a later date. His later adventures mostly turn on the exercise of his talent in speech, his cunning, or his dexterity evinced in his employment as the messenger of the gods. He also acted as charioteer and cupbearer to Zeus. He was active, full of bodily vigour, swift of foot, fertile in resources, cheerful, sensual.

The statues of Hermes, which were originally square blocks with a carved head upon them, were placed in the doorways of most private houses and temples at Athens. They were also erected where several roads met, to point out the way, and in the gymnasia, or public places of exercise. In early art, Hermes is usually represented with a chlamys, or cloak; a petasus, or travelling hat; talaria, or winged sandals; and a caduceus (κηρύκειον in Greek) or wand, with two serpents twined about it, in his hand. Originally the kerukion was an olive branch or staff—Hermes among his many benefits having taught mankind the mode of cultivating the olive. In later examples the chlamys is much reduced in size; the petasus is almost always, and the caduceus often, a pair of wings; and the god holds a purse in his hand, or is frequently represented with the right hand uplifted as the god of eloquence. In small works he is figured as psychopompos, conveying souls to Hades, &c. The representations of the deity in ancient works of art are very numerous, whether as single figures or as a portion of a group.

The original seat of the worship of this deity appears to have been Arcadia, whence it spread all over Greece. Temples dedicated to him were numerous, both in Greece and Rome. The festivals of Hermes were in Greece called *Hermaia*, (Ἕρμαια).

The Egyptian god *Thoth* was called Hermes by the Greeks. His attributes correspond in many respects with those of the Grecian deity. According to Plutarch ('Sympos.' Probl. 3), the Egyptian Hermes is said to have invented letters in Egypt. According to Diodorus Siculus, who appears to have confounded the attributes of the Egyptian and Grecian deity, he was the inventor of almost all the arts and sciences: a vast number of works are attributed to him.

HERMIT, more properly *Eremite*, from the Greek ἐρημίτης, signifying an inhabitant of a desert, is the name given to such religious persons as retired from society without becoming members of any monastic community. The distinction between hermits and monks, and the origin of both, are explained under the term MONACHISM. See also ANCHORET and ASCETIC.

HERNIA (from ἔρνος, *ernos*, a branch), signifies the protrusion of any organ from its natural position in the body; as hernia cerebri, hernia pulmonis, when the brain or lung protrudes through an aperture in the skull or the chest. But when used alone, this term means what is commonly called a rupture, that is, the protrusion of any portion of the intestinal canal from the cavity of the abdomen.

Herniæ sometimes form without any evident cause, the intestine being gradually protruded; but more frequently they result from some violent bodily exertion, as lifting heavy weights, excessive coughing or straining; or from sudden jarrings or shocks, as in jumping or falling; or from blows on the abdomen.

The general characters distinguishing a hernia are, a tumour, neither red nor hot, and often not painful, situated at some part of the abdomen, most frequently in or near the groin; largest when the patient stands up, and often disappearing entirely when he lies down; distended by coughing or other violent expiration, and liable to variation in size by exercise or rest, by abstinence or taking food; often producing disorders of the digestive canal, as flatulency, colic, &c. In the cases in which the hernia forms suddenly, as in consequence of a great exertion, the patient feels as if something had given way at the groin or other part of the abdomen, and on putting his hand there he feels a tumour which may vary in size from that of a nut to that of his fist, is elastic, hard, and tense, and soon after the accident becomes painful and tender. In the other class of herniæ, which may be called spontaneous, the tumour forms almost imperceptibly to the patient, and grows larger regularly but slowly; is attended with no pain, but merely a sense of weakness about the part; and decreases greatly or entirely disappears in the recumbent posture. If a hernia can be returned into the abdomen at pleasure, it is not by itself a dangerous disease; but if it become strangulated, that is, if the intestine is so constricted by the parts through which it has passed that its contents cannot pass through it, and its vessels are so much compressed that active inflammation is excited, it constitutes one of the most serious accidents to which the human body is liable. The symptoms indicating strangulation of the intestine are obstinate constipation of the bowels; pain and tenderness of the tumour, and spreading from it over the whole surface of the abdomen; extreme restlessness and languor; nausea and vomiting; a hard, small, and rapid pulse; thirst and coldness of the limbs. If the hernia be not reduced, these symptoms will regularly increase, till mortification of the intestine ensues, and (except in some most rare cases) death rapidly follows.

The above symptoms and other circumstances are common to all herniæ wherever situated, and are only modified slightly by the part of the abdominal contents protruded, the narrowness of the part through which it is forced, and the constitution of the patient. But there are some local circumstances peculiar to each, according to the part at which the intestine is protruded, which require to be noticed in connection with the mode of returning each into the abdomen and of retaining it there.

The most frequent kind of rupture is the Inguinal, and it is far more common in males than in females. It forms a tumour, occupying either the groin alone, or extending thence more or less obliquely downwards between the thighs. To reduce it the patient should be laid on his back with his loins lower than either his shoulders or his hips, and the knee of the side on which the hernia has formed should be raised and turned a little inwards. The operator grasping a convenient portion of the tumour with his right hand, should press it in the direction contrary to that in which it has protruded, and there retain it, while with his left finger and thumb placed at the narrowest part of the swelling he moves the intestine from side to side, alternately pressing and relaxing it, so as to empty some of its contents, and force it into the abdomen. If any portion be pressed through, a slight gurgling noise will be heard, and by continued efforts the whole will most probably follow.

An inguinal hernia may attain the size of an adult's head or more; but a Femoral hernia, which is the kind most common in females, is rarely more than two inches in diameter, and generally much less. It is usually of a rounded form, situated just below the groin, about two inches from the middle line of the body, and always feels hard and tense. The principal constriction is deep in the thigh, directly under the tumour, which tends to pass upwards over the groin. In reducing it the position of the patient should be the same as for inguinal hernia: if the tumour be large enough to grasp, it should be pressed directly backwards, as if to force it deeper into the thigh; but if it cannot be grasped, it should be pressed in the same direction, with the balls of the thumbs placed side by side upon it.

In Umbilical and Ventral herniæ, which come straight out from the front of the abdomen, the globular and pendant tumours which they form, and which often attain a considerable size, should be grasped with one hand, and pressed directly backwards towards the spine, while the opposite hand, as in inguinal herniæ, guides the successive portions through the aperture.

Whatever be the situation or condition of a hernia, it should be at once, if possible, reduced. The patient should go to bed, and, after lying a short time on his back, with his knees raised, the intestine will often of itself recede into the abdomen, especially if it have been frequently protruded; but if it do not, then the manual operation just described should be employed. The force used in it should never be so violent as to give much pain, and in old herniæ little or none should be caused; nor should the manipulation be continued for more than a quarter of an hour at a time, nor so long as to bruise the tumour or make it tender. If it fail, there are several auxiliary means that may be employed, of which a selection must be made according to the circumstances of each individual case. The warm bath should be first tried in all cases; the patient should be placed up to the neck in water at a temperature of from 94° to 100°, and remain there till he becomes quite faint. Any pain or irritation that previous attempts at reduction may have produced will be greatly relieved by these means, and the state brought on by the bath is peculiarly favourable for the return of a hernia, both by relaxing all the tissues surrounding it, and, when faintness occurs, by relieving the intestine from the pressure of the muscles, which often present the chief obstacle to its return, but which in that state become powerless. As soon therefore as the patient complains of faintness, or after he has been in the bath for ten minutes or a quarter of an hour, an attempt should be made to reduce the hernia by manipulating it as already directed under water. In strong and robust men, and especially in cases where the hernia has recently formed, bleeding to faintness, either before or while in the bath, should be employed, and the same opportunity taken to try to replace the intestine. The abstraction of blood will be useful, not only by the faintness which it produces being a favourable state for reducing the hernia, but by its relieving the inflammation which always arises when the intestine is strangulated, and by checking it in its fatal progress. If the warm bath and bleeding fail, the patient should be placed between warm blankets to recover from their depressing effects, and no more manual attempts should be made for some time. The next means employed should be the continued application of cold by ice or a rapidly evaporating lotion laid over the tumour, and kept there unless it produces much pain, till all the tissues are contracted and hard, for it is by their equable and powerful contraction on the intestine, and by the diminution of its volume, that reduction is sometimes thus effected even without manipulation. A hernia may be sometimes reduced by placing the patient under the influence of chloroform. Should this fail, and the symptoms of strangulation be increasing, the only means left before operation is the tobacco enema. Great caution is necessary in employing it; it should never be used except in otherwise healthy and tolerably strong persons, nor till the other means have failed. A dram of tobacco being steeped in a pint of boiling water for ten minutes, half the infusion thus made should be used first; and if it produce no evidently depressing effect, the other half may be injected in half an hour afterwards. The usual consequence is an extreme degree of languor and sinking, a kind of deadly coldness and paleness, and the last stage of depression: in this state a last attempt at reduction should be made; and if still unsuccessful, an operation must be resorted to. The tobacco enema should not be employed unless the symptoms of strangulation be quite evident. If the hernia seem merely irreducible, but is not strangulated, and if cold, and warm bath and bleeding (if deemed advisable), have failed, the patient should be left, and an active dose of aperient medicine given him, for sometimes the bowels will, under the operation of these means, return of themselves into the abdomen.

When the hernia has been completely reduced, its recurrence must be prevented by the wearing of a truss. A truss consists of a circular pad, having one side convex and soft, and the other flattened and made very firm by a plate of steel, by which the pad is riveted into the spring, which is a narrow band of highly tempered and very elastic steel, forming when extended somewhat more than a semicircle. In applying a truss, the soft convex surface of the pad should be placed accurately over the part where the neck of the tumour was situated, that is, over the ring through which the intestine first protruded, and which may be felt by the weakness of the abdominal walls, so that the finger may be easily pushed almost into the abdomen, carrying the skin and subjacent tissues before it. The pad being held there, the spring should be made to pass round the haunch to the back, so as to reach just beyond the spine; its elasticity, tending to bring its two extremities together, will thus act so as to press with a certain force upon the ring or the canal through which the hernia was protruded, and thus supply the defect of weakness at that part of the abdominal walls. At that extremity of the spring which is applied near the spine there is affixed, in what are called common trusses, a leathern band, which is to be passed round the opposite haunch, and buckled or buttoned on the pad, so as to prevent its shifting its position during exercise; and in some cases, where this is apt to occur, another band should pass from behind under and inside the thigh and be fixed to the pad. Another very useful form of truss is that commonly called Salmon and Ody's or the self-adjusting truss, which has a second pad, to be placed behind on the spine, and which requires no bands to keep it fixed, but, by the steady pressure of its two pads towards each other, maintains a firm pressure on the ring, and permits the spring to move up and down upon the haunch during exertion. In applying this, one pad must be placed on the ring, the spring must pass round the opposite haunch, and the hinder pad must rest on the spine, just below the loins, where it is least moveable. When there is a hernia on each side, a double truss, that is, one with a pad for each side, and one or two springs long enough to reach quite round the body, must be worn: if there be two springs, they should be connected by a cross-band and buckle, so that they may be tightened or loosened behind, and another band should pass from one pad to the other to maintain them in their proper position. To determine the necessary length for the spring of the truss, a measure may be taken by a string fixed at one end over the centre of the ring, at that part where, when the patient coughs, the intestine may be felt endeavouring to protrude, and thence carried round in an oblique direction between the most prominent part of the hip and the top of the haunch-bone to an inch beyond the spine. The pad should be of a size proportioned to that of the ring, and the spring should be strong enough to make firm but not painful pressure.

HERO, HEROIC, HEROISM. These words flow directly from the original Greek word *Ἥρως*, which denoted (at least in the times subsequent to the Homeric poems) a person intermediate between gods and men, and usually of divine descent on at least one side. Such were worshipped with divine honours by those cities and races of men which claimed them as their founders or ancestors. This divine origin however was not essential: thus Philippus of Crotona, who fell in battle against the Phœnicians and Egestæans, was made a hero for his beauty; a heroon, or shrine, was built on the spot where he was buried, and sacrifices were offered to him. ('Herod.,' v. 47.) At a later age Aratus and Brasidas were worshipped as heroes at Sicyon and Amphipolis; and the Athenians slain at Marathon received similar honours. Concerning these last, legends were current which show that a supernatural and mythological character was really ascribed to them, and they probably were the latest of the Greeks to whom such a character was attributed. The Heroic age, properly so called, appears however to have terminated with the immediate descendants of the Greeks who returned from Troy, and to have extended backwards for an uncertain length, estimated by Mr. Thirlwall at six generations, or about 200 years. This is the fourth or Heroic age of Hesiod, in which Zeus "made the divine brood of heroes, better and braver than the third or brazen race" ('Days and Weeks,' 157), the princes and warriors of mythological history, such as Theseus, Perseus, and those who fought in the sieges of Thebes and of Troy. In Homer the word hero occurs frequently, but in quite a different sense: it is applied collectively to the whole body of fighters, Argeii, Danai and Achæi, without reference to individuals of peculiar merit; and indeed often appears to be used for little more than an expletive, when *he*, or *the man*, or *the soldier*, would have done equally well. Indeed the application of the word is not even limited to warriors; but is applied to heralds, wise counsellors, kings, &c. It has been suggested, with considerable plausibility, that the word originally denoted the members of those roving bands who in the earliest times overran Greece, issuing forth from the south of Thessaly and giving extension to the name, first of Achæans, and afterwards of Hellenes, as we learn from the legends in Pausanias and Thucydides; so that in the same sense the Normans who colonised Italy, or the Saxons who settled in England, might justly be called heroes. The root of the word seems to be *her*, whence the Latin and German forms of herus and herr (master), here, hertha, heracles, vir, virtus, &c. The same root seems to exist in the word Arimann, which denoted a particular order of freemen among the Lombards, existing at the time of the establishment of their empire after the Lombard conquests. There seems little doubt that this class originated in the warrior caste of the Lombard invaders, and the establishment of the name thus furnishes an analogy to the theory suggested above as to the origin of the Homeric use of the word hero. Even the name of German, and the meaning of brother attached to the word in Latin, may originate in the same sense of a member of an armed family or body: the root in all cases appearing to involve the notion of might or mastery. The Sanscrit word *sūra* appears to contain the same element as "heros."

The promiscuous (or Homeric) use of the word hero disappeared in the age succeeding the Homeric poems. It seems probable that the Hellenic invasion, commonly called the Return of the Heraclidæ, put an end to it. The new conquerors of Southern Greece do not seem themselves to have borne or used the title; and afterwards, when they, or their descendants, looked back to the warlike legends of the earlier race who had borne the title, the lays, exploits, and persons were called heroic; and from the combined effect of poetical exaggeration, reverence for antiquity, and traditions of national descent, the more modern Greek use of the word arose, carrying with it notions of mythical dignity, and of superiority to the later races of mankind. The custom of showing respect or affection by making precious offerings, and celebrating costly sacrifices at the tombs of the dead; the imaginative temper of the Greeks, which, as it loved to ascribe a divine genealogy to the great, was equally willing to admit them to a share of the divine nature and enjoyments after death; and the love of magnifying past ages, common to all nations, will sufficiently explain the change of earthly leaders into protecting genii or dæmons, who were believed immortal, invisible, though frequenting the earth, powerful to bestow good or evil, and therefore to be appeased or propitiated, like the gods themselves. In the age of Hesiod, as is evident from the passage above referred to, the age of heroes was past, and they were already invested with their mythological character, which appears to furnish one, among other reasons, for believing him to have lived after the Homeric age.

In the common English use of the words a hero denotes only the chief or most distinguished person, the hero of a victory, or the hero of a novel. Hudibras is the hero of Butler's poem; but hero and heroism still preserve their original characteristics, and are applied to actions evincing an unusual or even superhuman degree of bravery and virtue.

(Thirlwall's *History of Greece*, ch. v.; *Philolog. Mus.* No. 4, 'On the Homeric use of the word *Ἥρως*;' Wachsmuth's *Hell. Alt.*; Von Savigny's *History of the Roman Law during the Middle Ages*, vol. i., ch. 4.)

HERO'DIANS (Ἡρωδιανοί, Matt. xxii. 16; Mark iii. 6; xii. 13; see also Mark viii. 15), were in all probability a political party in Judæa, who were anxious to preserve the government in the hands of Herod's family. By some the Herodians are thought to have been a religious sect; but they are not mentioned either by Philo, or by Josephus in his enumeration of the Jewish sects. In their religious opinions they probably belonged to the sect of the Sadducees, since that which is called by Mark (viii. 15) "the leaven of Herod" is styled by Matthew (xvi. 6) "the leaven of the Sadducees." They were no doubt the partisans and followers of Herod the Great. This view is supported by the Syriac version of the New Testament, which renders Herodians, by servants of Herod. Politically, they advocated compliance with the idolatries and customs of the Romans, to which the Pharisees were opposed; and this opposition throws light upon the snare laid for Christ in the question propounded by both sects (Matt. xxii. 16, 17) as to the lawfulness of paying tribute to Cæsar. As the answer seems rather in favour of the Herodians, the leaven of Herod must have consisted of the idolatry.

HEROIC AGE. [HERO.]

HEROIC VERSE, in its ancient sense, means that which was the vehicle of Greek, and subsequently of Latin, epic poetry, of which the actions of the heroes were the appropriate subject. [HEXAMETER.] In

English, our common ten-syllable couplet passes under this name, chiefly, it should seem, because it is the measure into which the epics of antiquity have been most frequently translated. The Alexandrine of twelve syllables, however, has been also used by our elder writers for this purpose, as by Chapman in his translation of the 'Iliad.'

HERPES. The word herpes was employed in a very vague sense, and applied to many eruptions of different kinds, until restricted by Willan to a well-defined affection of the skin, characterised by the eruption of clusters of transparent globular vesicles, situated on a red and inflamed base extending some lines beyond them. The vesicles of each cluster commonly vary in size from a millet-seed to a very small pea; the clusters themselves are distinct, being separated by portions of perfectly healthy skin, and they generally rise in quick succession.

The eruption is preceded and accompanied by a degree of constitutional disturbance which generally varies with the extent of the local affection, being often slight and attracting no notice, when this is limited and consists of a few clusters only, but very great and marked by a high degree of fever, when the clusters are numerous and spread over an extensive surface in a young and plethoric subject.

The local affection is announced by a sensation of heat and tingling experienced in the part, and first appears as a small bright red spot, having in its centre a few very minute vesicles. These vesicles, which contain a transparent colourless fluid, rapidly enlarge, and, in the course of some hours, attain the size and present the form and aspect of very small pearls: in the thickest part of the cluster two or three of the vesicles coalesce, forming one of irregular figure and larger size. There is a sensation of pricking and smarting pain experienced in the part. The vesicles gradually become opaque, in the course of a few days shrivel, and are succeeded by brownish scabs: the heat and irritation of the portion of skin on which they are situated subside; and the scabs fall off, leaving a tender and reddened state of the skin, which soon disappears. The duration of the individual clusters, from their first appearance to the falling off of the scabs, varies from one to two weeks. When there is a succession of clusters, they all follow the same march; the febrile state persists as long as fresh vesicles continue to arise, and the affection may be prolonged to three or four weeks. In some cases the fluid is absorbed, the vesicles shrivel, and, at the end of four or five days the affection terminates in desquamation; in others, the fluid in the vesicles becomes purulent, and they are succeeded, especially when seated on the back, by superficial ulcerations, which prolong considerably the duration of the disease.

The clusters of vesicles, though they retain in all cases the same characters, and follow nearly the same march, are sometimes confined to a particular locality, justifying the designation, *H. labialis*, *H. præputialis*, or assume a particular arrangement, giving rise to the varieties, *Herpes zoster*, when they are situated on one half of the body and extend in a line or band; *H. phlyctenodes*, when they are disseminated; and *H. circinnatus*, when they occur in circles or rings.

In *H. labialis* the clusters are disposed irregularly about the mouth, generally on the external surface of the lips, in some cases extending to the cheeks and alæ nasi, and in rare instances occurring also in the pharynx. It occasionally comes on after irregularities in diet, or unusual exposure to cold winds, or to the atmosphere, as in travelling; at the termination of the hot stage, in ague; and during the course of catarrhal fevers and pneumonia. It is always a slight affection in itself, requiring no treatment beyond that of the disorder which it accompanies.

Herpes præputialis. In this variety there are one or more small clusters of vesicles, either on the external or internal surface of the prepuce. When situated externally, they follow the ordinary march or terminate in desquamation, and require no treatment, with the exception of the application of lint soaked in the lotion of acetate of lead, for the purpose of alleviating the itching and preventing the rupture of the vesicles and the consequent formation of an ulcer. When they occur on the internal surface of the prepuce, the vesicles are kept continually moist, break at the end of four or five days, and often give rise to an excoriation or superficial ulceration, which by an inattentive observer may be mistaken for a syphilitic sore. It soon heals under the influence of cleanliness, the local application of the lead lotion, and the administration of a few alteratives.

In *Herpes zoster*, Shingles, there is a succession of clusters of white silvery vesicles, forming an oblique line or band, limited to one-half of the body, and almost always occurring on the trunk. It is generally ushered in by severe febrile symptoms, and by smarting or deeply-seated pains, which indicate the future course of the eruption. Each cluster follows the march we have described, and the febrile state continues as long as there is a succession of vesicles. It is unattended with danger, excepting in old persons, where the clusters are occasionally followed by gangrenous and sloughy sores. In young and plethoric subjects the treatment should consist of bleeding, saline purgatives, diet, and the application to the part of a sedative lotion. This treatment alleviates the sufferings of the patient, but has very little influence on the march of the vesicles.

Herpes phlyctenodes differs from the preceding variety in the arrangement of the clusters, which are disseminated, and have no particular seat. When occurring extensively, the vesicles do not attain the size common to more limited forms of the eruption. It is often met with in children during dentition.

In *Herpes circinnatus*, or herpetic ringworm, the eruption is limited in extent, frequently of a circular form, and consists of extremely minute vesicles, which dry up and terminate in exfoliation, leaving a scurfy areola. It occurs frequently on the cheeks in children, and in women of delicate complexion, and is often confounded with a disease entirely different in its nature, contagious, and also, in popular language, denominated ringworm. This form of Herpes soon disappears under the influence of the local application of almost any astringent solution.

None of the varieties of Herpes are contagious, and all occur most frequently in the young, during spring and autumn, and in warm climates.

The existence of distinct groups of vesicles on red and inflamed bases is sufficient to distinguish Herpes from every other cutaneous affection.

HERRING FISHERY. [FISHERIES.]

HERTHA, the Goddess of Earth among the ancient Germans. As Hertha, she was the wife of Thor; but Roman writers sometimes speak of the deity as *Herthus*, a male god, and the companion of Thor. Tacitus ('Mor. German.,' c. 40), who calls Hertha the mother of the gods, says that she was worshipped by the Suevi, and that her sanctuary was in a grove in an island of the ocean, and was served by a single priest. A chariot, covered by a cloth to conceal the goddess, was taken out of the sanctuary on certain occasions, and was drawn by cows about the country with great solemnity. This was a time of general rejoicing, especially for those places which were honoured by the visit of the goddess. During that time a cessation of war took place, arms were laid aside, and peace reigned over the land, until the priest thought proper to restore the goddess to her sanctuary, where the chariot and the clothing, and the goddess herself, or her image, it was said, were washed in a secret pond, and the attendants who assisted at these ablutions were immediately after swallowed up by the flood. The report of these mysterious circumstances served to inspire the ignorant people with a dread of the power of the goddess, whom no mortal could behold with impunity. (Grimm, 'Deutsche Mythologie.')

HESPE'RIDES, in Greek mythology, a family of Nymphs, of the same parentage, and apparently the same with the Atlantides, though there are differences between them, especially in number (the Atlantides being usually reckoned seven, and the Hesperides three in number), which we must leave to be accounted for by the general uncertainty of mythological story. They were named Ægle, Arethusa, and Hesperethusa, possessed the faculty of melodious song, and were the daughters of Atlas, by Hesperis, the daughter of Hesperus. Some traditions, however, add a fourth sister, Hestia; and Hesiod makes the Hesperides the daughters of Night. They dwelt in a beautiful garden in the western parts of the earth, in which grew the celebrated tree which bore golden apples, the gift of Ge to Hera on her marriage with Zeus. These apples were guarded by a fierce dragon named Ladon, which never slept. Heracles killed the dragon and carried off the precious fruit. Some authors make the treasure to consist of sheep instead of apples, both being called by the same Greek word, *mela*. Some think them citrons or oranges. The Gardens of the Hesperides are variously placed, in an oasis of the African desert, in Cyrenaica, at the foot of Mount Atlas, and in the Happy Islands of the Atlantic.

HESPERIDIN. A neutral vegetable principle obtained from the spongy part of the peel of oranges and lemons, by digesting it in boiling water, and saturating the infusion with cream of lime, then evaporating to dryness, treating the residue with alcohol, and evaporating the filtered solution. The matter left is to be treated with twenty times its weight of distilled vinegar, and the solution set by for a week, when the hesperidin is deposited, and is to be purified by recrystallisations from alcohol.

The properties of hesperidin are: It forms white silky needles, grouped in tufts or in mammilated forms; they are inodorous, insipid, fuse at a gentle heat into a resinous substance which becomes electrical by friction; at a higher temperature, this substance decomposes without yielding ammonia, and burns with flame and an aromatic odour. It is insoluble in cold water, and requires sixty parts of boiling water for solution; it is very soluble in boiling alcohol, but insoluble in ether. Nitric acid renders hesperidin yellow; sulphuric acid gives it first a yellow and then a red tint; hydrochloric acid imparts a greenish yellow colour to it. The acetic solution of hesperidin is not decomposed by water; persulphate of iron precipitates it brownish-red; it is soluble in the alkalies. No analysis has as yet been made of hesperidin.

HESSENES. [ESSENES.]

HESTIA. [VESTA.]

HETEROGENEOUS. [HOMOGENEOUS.]

HETEROSCII (other-shadowed), an old astronomical term for persons living in such parts of the earth that their shadows at noon are always turned contrary ways. Thus the only heteroscii are those who are situated without the tropics, and in different hemispheres; since in the northern hemisphere those who are situated north of their tropic have the shadow at noon always turned northward, and those south of the southern tropic, southward.

HEVEENE (CnHn). An oily hydrocarbon found amongst the products of the destructive distillation of caoutchouc.

HEXACHLORXYLON ($C_{20}H_6Cl_6O$ or $C_{10}H_4Cl_4O_4$). A yellow crystalline derivative from creasote, obtained by the action of hydrochloric acid.

HEXACHORD (ἑξ, *six*, and χορδή, a *gut*, a *string*), a name given by the ancient Greeks to a lyre of six strings; also a scale of six sounds. In what is denominated 'the System of Guido," musical sounds are divided into three scales, named *Hexachords*. The first, from C to A, is called the *Natural* hexachord: the second, from G to E, the *Durum*; and the third, from F to D (the B flattened), the *Molle*. To the notes of each scale are assigned, as names, the syllables *ut*, *re*, *mi*, *fa*, *sol*, *la*. This perplexing and irrational system, which has been well designated *Crux tenellorum ingeniorum*, is now utterly discarded.

HEXAGON, a figure of six sides. [Regular Figures.]

HEXAHEDRON, a solid of six faces. [Cube; Regular Solids.]

HEXA'METER (ἑξ, six, *μέτρον*, measure) is the most important form of dactylic verse. [Dactylics.] It consists of six feet, either dactyls or spondees, with no limit in their arrangements, except that the fifth is usually a dactyl, and the sixth invariably a spondee. Great part of the beauty of a long poem written in this measure depends on the varied cadences, which may be produced by varying the cæsura. [Cæsura.] The most usual places are the middle of the third and the middle of the fourth foot: of these, the former is called by prosodians the *penthemimeral*; the latter, the *hephthemimeral cæsura*; as, for example:—

> Vix e conspectu | Siculæ telluris in altum.
> Non aliter quem qui adverso | vix flumine lembum.

That which is called the *bucolic* cæsura, at the end of the fourth foot hardly seems to deserve special mention, being in no respect essential to the harmony of the verse, and invariably accompanied by one of the two before mentioned. These are essential; and one or other of them is always observed in well-constructed verse, except in rare cases where the omission is intentional, with a view to some special effect. For the niceties of the measure, see the treatise of Hermann, 'De Metris,' lib ii. 32.

HEXAPLA, the plural of ἑξαπλοῦς, which means "six-fold," was an edition of the Scriptures of the Old Testament prepared by Origen, which exhibited, in addition to the original Hebrew text, six Greek versions in as many parallel columns; namely, the Septuagint, that of Aquila, that of Symmachus, that of Theodotion, one found at Jericho, and one found at Nicopolis in Epirus. It also comprehended a seventh version of the Psalms. The Hebrew text was besides given both in Hebrew and in Greek characters; so that, properly speaking, there were eight columns in all, whence the work is sometimes called Origen's Octapla. [Bible; Septuagint; and Origenes and Theodotion, in Biog. Div.]

HEXYL. [Caproic Alcohol, *Hexyl.*]

HEXYLENE ($C_{12}H_{12}$), *Oleene*, *Caproïlene*. The olefene of caproic alcohol. It is obtained by distilling hydroleic acid, and is also probably formed by the destructive distillation of many other fatty bodies. It is a colourless very mobile liquid, lighter than water, and possessing an arsenical odour. It is scarcely soluble in water, but easily so in alcohol and ether. Hexylene boils at 131° Fahr., and its vapour appears to exercise a deleterious influence upon animals. Birds which have inhaled it for some time fall dead.

HIERO'S FOUNTAIN, a philosophical toy illustrating some hydrodynamic details. It consists of three vessels connected by two tubes. Water descending from the top vessel, drives the air from the bottom into the middle vessel and compresses it, so that by its elasticity it forces the water in this vessel up a jet. It is only another form of *compressed air-fountain*.

HIEROGLYPHICS, a compound Greek word, meaning "sacred engravings," generally applied to the representations of animal and other forms sculptured on the monuments of Egypt, by means of which the Egyptians expressed their language. The ancient Greek authors call this mode of writing *hieroglyphic*, or *hierographic*, and attribute its invention to Thoth, the Egyptian Hermes. According to these authorities, it was the most ancient mode of writing known to mankind. It was called by the Egyptians *Neter tu*, or "sacred words," and was particularly used in all inscriptions relating to the gods, temples, and public events. Above 1000 different symbols appear on examination of the monuments to have been employed, and future observations will probably still further augment their number. These are arranged with great precision on the monuments, generally in horizontal or vertical lines, with all the animals and symbols of the same inscription facing in the same direction, whether to the right or to the left; sometimes, however, they are placed in the area, or field, and dispersed amongst the figures or scenes they are intended to illustrate. They have been divided into six classes: 1, sculptured and not painted; 2, those which are sculptured and painted; 3, *linear*, or drawn in outline; 4, drawn in outline and painted; 5, *polychrome*, or those painted with many colours; 6, *monochrome*, or those painted in one colour. Those carved on stone are generally executed in a peculiar kind of sculpture, called *cavo rilievo*, in raised relief below the surface, but sometimes in bas relief. The linear hieroglyphics are drawn with a carbonaceous black or a vermilion red ink, on papyri, linen, slices of stone, wood, and other materials. Hieroglyphics appear in use on the walls of the earliest tombs, and even scrawled on the blocks of stone of the great Pyramid built by Cheops, and they continued to be employed till the time of Caracalla, during a space of almost 3000 years; but subsequently were superseded by a more cursive writing called the Demotic; and finally, on the triumph of Christianity, by the modern Coptic. Some scattered notices of their general nature and the meaning of a few symbols are given by Diodorus, Chæremon, Clement of Alexandria, and Porphyry; and a special dissertation upon them, written by Horus Apollo, or Horapollo, of Phenebethis, A.D. 500, has been handed down; but a knowledge of them was little cultivated by the Greeks and Romans, even those who lived in Egypt itself. From the 10th century to the 16th century, all knowledge of them totally disappeared; and on the revival of learning, the task of decipherment and interpretation was vainly attempted, till the discovery of the Rosetta stone in 1799 gave a clue to their interpretation. This monument, found on the site of a temple dedicated by King Necho to the god Atum, which is a trigrammatical inscription in hieroglyphics, Demotic or cursive writing, and *Greek*, recites the decrees of a synod of priests assembled at Memphis, A.D. 196, in honour of Ptolemy V., their benefactor, and declares that the decree is ordered to be engraved in these three writings. After some feeble, although not unsuccessful, attempts to decipher the demotic by De Sacy and Akerblad in 1802, Young, in 1814, was the first to discover from the name of Ptolemy on this stone, and that of Berenice on a doorway in the south quarter of Karnak, that certain hieroglyphics were employed to represent sounds, not ideas, as had been hitherto conjectured. The removal by Bankes of a small obelisk from Philæ, erected by the priests in honour of Ptolemy Euergetes II. and Cleopatra, on the pedestal of which they had inscribed a Greek inscription, enabled Champollion in 1822 to compare the names of Cleopatra and Ptolemy, and, correcting some of the errors of Young, to extend the alphabet, and lay the foundation for the future decipherment and interpretation of the hieroglyphics. It was seen, from a comparison of these names and the recurrence of the same hieroglyphics in the same places, as if they were used as sounds, that this was their true employment; and by an extension of the decipherment, the names and titles of the Ptolemies, Roman emperors, and native monarchs, were readily discovered.

Since the time of Champollion, who published a Grammar in 1836, and Dictionary of Hieroglyphics in 1841, the study of the hieroglyphics has been pursued by Rosellini, Salrolini, Leemans, Lepsius, Brugsch, De Rougè, Birch, Goodwin, Hincks, and others.

The general results of these inquiries have shown that all hieroglyphical inscriptions, from the most remote to the latest periods, consist of two classes of characters, the first called by the Egyptologists *ideographs*, or symbols representing ideas, not sounds; and *phonetics*, or hieroglyphics employed as syllables, or letters of the alphabet. The great body of the inscriptions are composed of phonetics, at least to the extent of four-fifths of each entire text; and they are easily distinguished by their constant recurrence. They are, however, fewer in number than the *ideographs*.

These ideographs are divided into two classes: 1. The *ideographs* proper, or those which represent only one idea; as a seated man having the head of an ibis, to mean the god Thoth or Hermes; a wolf to represent that animal; and a bundle of flax to represent flax: these are direct imitations. 2. Those of the kind called by Clement *tropic*, or enigmatic, or metonymes, express the idea by less direct means, as a smoking pail, to signify milk; a pelican seizing a fish, to signify fishing; an ape, to express anger, on account of the irritability of the animal; and a jackal, cunning, on account of its crafty nature; an ostrich-feather, to signify truth, because all the feathers of the wing of that bird were supposed to be of equal length. These ideographs are often preceded by a group of *phonetics*, which spell the sound of the word, the sense of which they are intended to convey: thus, the wolf is preceded by a hare, A, a line of water, N, and a basin, SH, spelling *Ansh*, "wolf;" and the jackal by the back of a chair, S, and chisel, B, spelling *sab*, "crafty." These direct ideographs are the oldest part of the system, the remains of the primitive picture writing of the nation: about 700 have been found.

The *determinatives* form a sudivision of the ideographs, and are those symbols employed to represent more than one idea. They are extensively employed and repeated in the inscriptions. Some of these determinatives are employed in twenty similar senses, others convey two or three similar ideas. Their use is to abridge the too copious employment of ideographs, and to render clear the ambiguity of phonetic groups. Thus, the *sun's disk*, represented as a circle with a dot in the centre, signified all ideas connected with that luminary, as the sun, year, month, hour, day, night, light, darkness, orbit, festival; an *uræus* signified any goddess in the Pantheon, a seal-ring, to shut or to enclose. These determinatives, like the ideographs, are preceded by groups of phonetics, spelling the sound of the ideas they convey—thus, the sun's disc has before it phonetics reading *aten*, when it means a disc, and *tar* when it means "time." They *determine* in fact the genus of the idea of the phonetic group, and are often used instead, or in place of their corresponding ideographs, which are pictures so elaborate of the idea as to be unsuited for general purposes, and only fit for the most magnificently executed public monuments. Sometimes two determinatives, or an ideograph and determinative, are used after a phonetic group.

These determinatives in fact resemble the 214 keys or radicles of the Chinese, which are used in nearly the same manner. Similar determinatives were employed, although on a more limited scale, in the Assyrian and Babylonian cuneiform inscriptions, and were not abandoned in cuneiform systems till the time of the Persians, B. C. 525, only yielding way to the invention of the alphabet by the Phœnicians. About 170 hieroglyphic determinatives have been recognised. The discovery of this portion of the hieroglyphical system is due to Champollion, and he interpreted the sense of these two classes of ideographs by comparing the symbols with their explanation, when it remained, in ancient classical authors, by a careful analysis of the Rosetta inscription, by a due regard to their position in sentences, and by the analysis of the phonetic groups which preceded them. The discovery of the phonetic system, in fact, aided to discover the meaning of the ideographs and determinatives, and these in their turn shed light on the meaning of the phonetic groups. The 170 determinatives embrace the whole circle of ideas, and are used in the hieratic or cursive writing without ideographs, and accompanied only by their proper phonetic groups.

The hieroglyphics used to represent sounds, called *phonetics*, are fewer in number than the preceding, forming, however, a complete syllabarium of the spoken language. These syllables fall into two classes. Those ending with vowels, 52 in number, represent 18 sounds of the spoken language, and answer the purposes of a pure alphabet. They were sounded either according to the primitive pronunciation of the symbol chosen, or else according to the initial sound of the hieroglyph; thus a mouth, *ro*, represented the liquid R or L; and a hawk, *aakhom*, the vowel A; an owl, *mouladj*, its initial sound M. At the earlier period of the formation of the language some of these phonetics are preceded and followed by one already in common use, having the same sound: thus, a flying goose has before it a blind or window-mat P, and after it the eagle A, and placed in the centre of the group it is demonstrated or explained to have the syllabic value of PA. Each of these 54 letters, in fact, have, at the option of the scribe, the final hieroglyphic vowel which completed their syllable written after them, but by degrees this fell into desuetude, and they finally became almost purely alphabetic. To these must be added 57 hieroglyphs used for syllables terminating in consonants. These, like the preceding, have such hieroglyphs of the alphabetic series as represent their initial or final signs indifferently written before or after them, or omitted. For example, a star is used for the syllable SEB or SEV, sometimes with the back of a chair, the alphabetic S written before, in, and often with the leg, the alphabetic B or V after it. In some rare instances both the alphabetic hieroglyphs S and B are written before and after it, enclosing as it were the star in the midst. The whole of these hieroglyphic syllables are monosyllabic, and were sounded according to the primitive name of the object. These *phonetics* continued in general use till the age of the 22nd dynasty, or about B.C. 1000, when several ideographs were added by the priests, for alphabetic and syllabic sounds, and this innovation, which went on increasing till A.D. 200, when the number amounted to about 90 additional characters, gives a complex alphabet and syllabarium of nearly 200 hieroglyphics in common use.

The phonetics formed the great body of the language, all the grammatical forms, and abstract prefixes and affixes, substantive and auxiliary verbs, being composed of them only. Groups of phonetics precede or replace the ideographs and determinatives, and give the sounds of the ideas intended. They are constantly interchanged among themselves, and these equations of sound are called *variants*. In the long interval of nearly 3000 years, the many papyri containing similar texts give hundreds of words written with different symbols.

It is now necessary to say something of the nature of the language as shown by the phonetics. The words are principally Coptic, but this language has lost so much of its vocabulary that it is inadequate to explain half the hieroglyphical words, which amount to about 4000. The verbal root in hieroglyphics is unchangeable, the nouns and adjectives being declined by prefixes, as *bak*, a hawk, *pa bak* the hawk, *en bak*, of a hawk, *er bak*, to a hawk; the plural has *iu* added as *bak-iu*, hawks. The verb is conjugated by affixes, as *maa* to see, *maa a* I see, *maa na*, I saw, and auxiliaries, as *au a her maa*, I was seeing or saw. The pronouns are very numerous. The prepositions are often vague, and appear in their original composite form, which they have lost in most other languages, thus, *her hat* "over the heart," is "in the midst," *em-khen* "in the hall" is "within." The syntax is exceedingly regular, the verb appearing first, then the objective, and finally the instrumental case. Some verbs are transitive, others neuter, and the genders of nouns are indicated by affixes and prefixes. The distinction between active and passive is but slight.

With respect to style, the monumental, except where colloquies are introduced, is elliptic and laconic, and the hieratic style of the Ritual and religious works partakes of the same characters. Even verse or rhythm has been found; the expressions are flowery with oriental imagery, antithesis and metaphor. The lapidary hieroglyphical inscriptions are almost all religious, historical, or sepulchral. With the exception of the Ritual, [PAPYRI] the books of the Egyptians were written in a cursive or writing hand, of a very distinct clear shape, like our ancient court or law hand, in horizontal lines with headings at the top of the page, and rubrics. This *hieratic* character, as it is called, employed far fewer symbols than the hieroglyphic, and approached nearer to the alphabetic system, but still made a copious use of determinatives. It has been traced up as early as the 6th dynasty, and continued till the 2nd or 3rd century, A.D. It was also employed for official documents, correspondence, memoranda, and drafts, as the only written language till the commencement of the 26th dynasty, about 800 B.C., when a second written language was introduced, called the *epistolary*, *demotic*, or *demodic*, that is, popular, or *enchorial*, that is, native. After the 8th century B.C., the hieratic was only used for religious purposes, chiefly copies of the Ritual. At its commencement, the *demotic* was only an abridgment of the hieratic, but it rapidly lost all resemblance with hieratic forms, abandoned to a great extent, although not entirely, the use of ideographic and determinative signs, and endeavoured to accommodate the written language as nearly as possible to the alphabetical Phœnician and Greek systems then known to the Egyptians. It continued in use till the 3rd century, when it was finally superseded by the Coptic; the triumph of Christianity in Egypt having done away with the last form in which the vain superstitions of paganism remained enshrined in the writings of the Valentinians, Gnostics, and other heretics. The demotic was extensively used under the Ptolemies and Romans for letters, and other documents, and was first learnt by youth, who, after they had mastered it, according to Clement, proceeded to learn the hieratic and hieroglyphic, then an old and dead writing, the knowledge of which was only to be acquired by a special study. The demotic, although it may appear paradoxical, is the most difficult of the Egyptian cursive hands to decypher, while the documents written in it have less attraction to the student from the dry nature of their contents.

Besides the Egyptians, the ancient Æthiopians also carved hieroglyphics on their pyramids and public monuments. These resemble those used during the later days of the Egyptian monarchy, and expressed the sounds of the Amharic or Æthiopic dialects: they have not yet been interpreted. The elder Democritus, B.C. 459, wrote, it appears, a dissertation on Æthiopian hieroglyphs. At Nineveh, Koyunjik, and even in the isles of the Greek Archipelago, objects have been found with hieroglyphical inscriptions, not in the Egyptian language, perhaps unmeaning imitations, like the obelisks erected by some of the Roman emperors.

The term hieroglyphics has also been applied to the writings and paintings of the ancient Mexicans, by which they depicted the various occurrences of life. The Mexican system was more pictorial than the Egyptian, the subjects were actually painted, but certain symbols or hieroglyphs were introduced to aid their explanations. The symbol expressive of the king's name is attached by a cord over the head of the figure of the monarch, that of the name of persons, of towns, and hills, is expressed in the same manner. After the introduction of Christianity some of the symbols were employed phonetically. This symbolical system of pictorial writing prevailed in Central America and Yucatan before their conquest by the Spaniards.

The term hieroglyphics was also used by writers in the 16th century to certain emblemata which they invented and illustrated, and by astrologers and almanac makers to the symbolical pictures, by which they pretended to show the events likely to happen in the course of the year.

(For the principal works on hieroglyphics, the reader is referred to Young, *Account of Discoveries in Hieroglyphical Literature*, 8vo. Lond. 1820; Champollion, *Précis du Systéme Hièroglyphique*, 8vo., Paris, 1824; *Grammaire Égyptienne*, fo., Paris, 1836; Lepsius, *Lettre à M. Rosellini*, 8vo., Rome, 1837; Brugsch, *Scriptura demotica*, 4to., Berlin, 1848; Birch, *Introduction to the Study of the Hieroglyphs*, 12mo., London, 1857.)

HIGH COMMISSION COURT, a tribunal established by Queen Elizabeth under the authority of a clause in the Supremacy Act (1 Eliz. c. 3), which exercised arbitrary power in matters of faith and in ecclesiastical concerns, as the Star Chamber did in civil affairs. The commissioners were forty-four in number, of whom twelve were ecclesiastics, and three commissioners constituted a quorum. Their jurisdiction extended over the whole of the kingdom, and was not confined to the clergy, but included all classes. They were directed to visit, reform, redress, order, correct, and amend all errors, heresies, schisms, abuses, offences, contempts, and enormities whatsoever, which by any ecclesiastical authority whatever might be lawfully ordered or corrected. The commissioners, or any three of them, judged at their own discretion of any speech or writing which tended to heresy or schism. All appeals from the inferior ecclesiastical courts were carried before the Court of High Commission. The court was empowered to punish incests, adulteries, fornications, and to inquire into matters relating to matrimonial offences. Other ecclesiastical courts had been subject since the Reformation to inhibitions from the supreme courts of law, but this court was exempt. It exercised its powers therefore without control, and was authorised to conduct its proceedings, not only by the ordinary legal processes, by juries and witnesses, but to use "all other means and ways which they could devise." This empowered them to resort to the rack, to torture, inquisition, and imprisonment, and to proceed, not upon information, but at their own discretion upon rumour and suspicion. The court could bring before it a suspected person, and by administering to him an oath, compel him to answer any question, and thereby criminate himself or his friends. Refusal to take this oath was punishable by imprisonment.

Fines were levied which often ruined the offender, and he might b imprisoned for any length of time at the discretion of the court. Th great object for which the court was established was more especially to punish any departure from the Act of Uniformity in matters of religion or in the services and ceremonies of the Established Church. Elizabeth, in a letter to the Archbishop of Canterbury, said she was resolved "that no man should be suffered to decline, either on the left hand or on the right hand, from the drawn line limited by authority and by her laws and injunctions." The Commons remonstrated feebly against the tyranny of the Court of High Commission, and by way of answer she granted towards the close of her reign a new patent in which the powers of the court were in some respects extended.

In the reign of James I. the sentences of the Court of High Commission were most generally confined to deprivation; but when the Commons remonstrated on account of its proceedings he refused to interfere. In 1610, by virtue of the royal prerogative, he established a Court of High Commission in Scotland, the authority of which was readily acknowledged by the bishops and some of the clergy.

In 1641, the Court of High Commission and the Star Chamber were both abolished, and a clause was introduced into the act which prohibited the revival of the former court or any other of a like nature. James II., however, issued a new commission, and appointed seven commissioners to exercise full and unlimited authority over the Church of England, and with the full powers of the former courts. Sancroft, archbishop of Canterbury, refused to be a member. Four of the commissioners were bishops, and the three laymen were the Earl of Rochester, Chancellor Jeffries, and Lord Chief Justice Herbert. The Revolution swept away this arbitrary institution.

HIGH CONSTABLE. [CONSTABLE.]

HIGH STEWARD. [STEWARD, LORD HIGH.]

HIGH TREASON. [TREASON.]

HIGHWAY. [WAY.]

HINDU ARCHITECTURE. [INDIA, ARCHITECTURE OF.]

HINDU CASTES. The division of the Hindus into classes or castes, with fixed occupations, existed from the earliest times: the word caste is derived from the Portuguese word *casta*, "race," or "lineage;" in Sanskrit they are called *varnas*, that is, "colours." The most ancient portion of the Vedas alludes to such a division; and in the laws of Manu, the Ramayana, the Mahabharata, and all the other Sanskrit works of the greatest antiquity, we find the system of castes fully developed. The Greeks who visited the country describe its inhabitants as distributed into certain classes. (Arrian, 'Indic.,' c. 11, 12; Diodor. Sic., ii., c. 40, 41; Strabo, xv., c. 1, pp. 485-6, Casaubon; Pliny, 'Hist. Nat.,' vi., c. 19.) We have no means of ascertaining the origin of this institution. Heeren supposes that it was founded upon conquest; the first three tribes being a foreign race, who subdued the aborigines of the country and reduced them to an inferior caste: while others trace it "as the result of that fondness of perpetuating, like heir-looms, by descent from father to son, certain offices or the exercise of certain arts and professions, which is so peculiarly characteristic of almost all nations of the Indo-Germanic race."

All the Hindu writings recognise only four pure castes: Brahmans, Kshatriyas, Vaisyas, and Sudras. Pliny ('Nat. Hist.,' vi. 19) appears to have heard of the same number; but Megasthenes, from whom Arrian, Strabo, and Diodorus Siculus derive their account, mentions seven classes:—1, philosophers; 2, agriculturists; 3, herdsmen and hunters; 4, handicraftsmen and artizans; 5, warriors; 6, public inspectors; 7, royal councillors. But Megasthenes has evidently separated into distinct classes individuals belonging to the same class; the public inspectors and royal councillors belonged without doubt to the Brahmanical class, as well as the philosophers; the agriculturists, herdsmen, and hunters to the Vaisyas; and the handicraftsmen and artizans to the Sudras.

The following extract from the 'Jatimala,' a Sanskrit work on Hindu castes, gives the common Hindu tradition respecting the origin of each caste. "In the first creation by Brahma, Brahmanas proceeded, with the Veda, from the mouth of Brahma. From his arms Kshatriyas sprung; so from his thigh Vaisyas, from his foot Sudras, were produced: all with their females. The Lord of Creation viewing them, said, 'What shall be your occupations?' They replied, 'We are not our own masters; oh, God, command us what to undertake.' Viewing and comparing their labours, he made the first tribe superior over the rest. As the first had great inclination for the divine sciences (*Brahme veda*), therefore he was Brahmana. The protector from ill (*Kshayate*) was Kshatriya. Him whose profession (*Vesa*) consists in commerce, which promotes the success of wars for the protection of himself and mankind, and in husbandry and attendance on cattle, he called Vaisya. The other should voluntarily serve the three tribes, and therefore he became a Sudra; he should humble himself at their feet."

A strong line of demarcation is drawn between the first three castes and the Sudras. The former are allowed to receive instruction from the Vedas, and are considered to have been born again in a spiritual sense, whence they are called regenerate. The emblem of this second-birth is a peculiar kind of girdle or cord, which differs according to the caste; and with which a Brahman may be invested from his eighth to his sixteenth year, a Kshatriya from his eleventh to his twenty-second year, and a Vaisya from his twelfth to his twenty-fourth year; hough in certain cases the investiture may be made in the fifth, sixth, or eighth year respectively. ('Manu,' ii., 36-38.) A Sudra on the contrary is not reckoned among the regenerate; and would, according to the ancient Hindu law, be put to death for reading the Vedas.

The Brahmans possess the exclusive privilege of teaching the Vedas, and were in former times in the exclusive possession of all knowledge. Though the sovereign of the country was chosen from the Kshatriya class, the Brahmans possessed the real power, and were the royal councillors, the judges, and magistrates of the country. ('Manu,' viii. 1, 9, 11.) Their persons and property were inviolable; and though they committed the greatest crimes, they could only be banished from the kingdom. ('Manu,' viii. 380.) They were to be treated by sovereigns with the greatest respect; for "a Brahman, whether learned or ignorant, is a powerful divinity." ('Manu,' ix. 313-317.) The curse of a Brahman could consign even the gods to misery; and the Ramayana and Mahabharata contain numerous instances of the withering effects of such a curse.

The proper duty of a Brahman is to teach the Vedas, to perform sacrifices to the gods, and to meditate upon divine and holy objects. At an early age he is placed under the instruction of a Brahman, called a *Guru*, whose commands he is bound to obey, and whom he must reverence as a spiritual parent. When he arrives at years of maturity it becomes his duty to marry, and to lead a life of religious contemplation. He ought to be supported by the contributions of the rich, and not to be obliged to gain his subsistence by any laborious or useful occupation. But as all the Brahmans could not be maintained by the working classes of the community, it was found necessary to allow them to engage in other occupations; and it is accordingly provided in the laws of Manu, that a Brahman, unable to subsist by his religious duties, "may live by the duty of a soldier, and if unable to get a subsistence by this employment, may subsist as a mercantile man, applying himself to tillage and attendance on cattle." ('Manu,' x., 81, 82.) In seasons of distress a further latitude is given. The practice of medicine and other learned professions, painting and other arts, work for wages, menial service, alms and usury, are among the modes of subsistence allowed to Brahmans. (Colebrooke, 'On Indian Classes,' in 'As. Res.' vol. v.; 'Miscell. Essays,' vol. ii., pp. 186-7.)

The Brahmans still hold the first rank in Hindu society and are treated with great respect in all parts of Hindustan. But in consequence of the conquest of the country by foreign rulers, and the prevalence of many sects that have rejected their authority, they no longer possess the power they once enjoyed. The increasing acquaintance of the Hindus with the English language and literature, and the establishment of public schools, are tending still further to diminish their influence.

The Brahmans are separated into two great classes, one of which occupies the countries towards the north, and the other the countries towards the south. The southern Brahmans "hold in great contempt those from Kasi or Benares, as being men from the north; and would not even admit them to the honour of eating in their houses. The northern Brahmans are however at least as proud as those from the south, and allege several reasons for holding them in contempt; among which the most urgent is, that the women of the southern Brahmans are allowed to appear in public." (Buchanan's 'Journey from Madras through Mysore,' &c. In the Deccan the Brahmans are also divided into Vaidikas, who subsist by charity, and dedicate their lives to study and devotion; Lokikas, who follow worldly pursuits; and Numbis, who officiate in temples and perform menial duties to the idols.

The Kshatriya, or military class, is said by the Brahmans to be extinct. The decay of the Kshatriya class may have been owing to the peaceful habits of the people and their freedom from foreign invasion, and the consequent want of employment for a military class. But according to an ancient tradition the Kshatriya caste was destroyed by Parasu Rama, the sixth incarnation of Vishnu, and their land bestowed upon the Brahmans. The laws of Manu appear to refer to the same tradition in a passage where a list of Kshatriyas is given who, "by the omission of holy rites and by seeing no Brahmans, have gradually sunk among men to the lowest of the four classes." (x. 43, 44.)

The duty of the Sudra is servile attendance upon the higher classes, and especially the Brahmans, but he may also follow mechanical occupations, as joinery and masonry, and practical arts, as painting and writing; and although a man of a lower tribe is in general restricted from the arts of a higher class, the Sudra is expressly permitted to become a trader or a husbandman. (Colebrooke, 'On Indian Classes'—'Miscell. Essays,' vol. ii., p. 187.) The statements of Robertson, Mill, and many other writers, respecting the strictly hereditary nature of all trades and occupations in India, are considerably exaggerated. The liberty which is given to the Brahmans, even by the laws of Manu, has already been remarked; and a similar latitude is allowed to the Kshatriya and Vaisya classes. Mr. Colebrooke, whose opinion, from his extensive acquaintance with Hindu literature, and from his long residence in India, is entitled to the greatest respect, remarks, "that almost every occupation, though regularly it be the profession of a particular class, is open to most other tribes; and that the limitations, far from being rigorous, reserve only one peculiar profession, that of the Brahmana, which consists in teaching the Veda, and assisting at religious ceremonies." It is the opinion of some Europeans who have acquired an accurate knowledge of the manners and customs of the natives, that Europeans in general give too much credit to the assertions of the natives concerning the rules of their caste, which are commonly alleged as an excuse for declining any duty that is disagreeable.

A great portion of the population of India does not belong to any of the four pure castes. The individuals who form what is usually termed the impure or mixed classes, called in Sanskrit *Varna-Sankara*, that is, "mixture or confusion of classes," are either the original inhabitants of the country who have never professed the Hindu faith, or persons who originally belonged to one of the four pure classes, and have either lost caste themselves, or are descended from those who had lost caste, or the offspring of marriages between persons of different castes. The faults which occasion a lost of caste, and for which no pardon can be given, are—1, Sexual intercourse within the prohibited degree of consanguinity; 2, Sexual intercourse with any prohibited class; 3, Eating forbidden fruit, or drinking intoxicating liquors; 4, Stealing; 5, Slaying any animal of the cow kind, or of the human species; but a Brahmin is permitted to kill his enemy in battle; 6, Eating in company with persons of another caste, or of food dressed by their impure hands.—7, Eating on board a ship food that has been dressed there; 8, Omitting to perform the ceremonies due to deceased parents. But the greater number of impure or mixed classes has arisen from the intermarriage of persons of different classes.

Numerous other classes are formed from the intermarriage of the twelve mixed classes that have already been enumerated. One of the best known of the impure classes is that of the Pariahs, a corruption of the Tamul name *Parriar*, in the Deccan. They are called *Maliwanlu* in Telingana, and *Walliars* in Carnata. Their numbers are very considerable.

There are other tribes, which are considered inferior even to the Pariahs. Such are the *Pallis* and the *Pulias*, in the southern part of the Deccan; the *Curubarus*, the *Lambadis*, the *Dumbarus*, the *Chensu Carirs*, and many others.

HINGE, a kind of joint, usually made of iron or brass, upon which doors, gates, shutters, box-covers, &c., are made to turn in the act of opening and shutting. Hinges are constructed in a great variety of forms; but in most of the commoner kinds the action is that of a hollow cylinder working round a fixed central pin. In Collinge's patent hinges, which are peculiarly adapted for hanging large heavy doors and gates, the principal rubbing action is between a hollow cap and an accurately turned sphere, formed, as it were, upon the end of a pin: a cavity being provided for the reception of a supply of oil to lubricate the rubbing surfaces. Redmund's rising hinges, so frequently used for hanging room-doors in houses of superior character, have, like ordinary hinges, a hollow cylinder divided into two or more portions, attached one to the door and one or more to the door-post; but instead of the hollow cylinders being divided transversely *at right angles*, they are divided by spiral or rather helical lines. The result of this contrivance is, that when the door is opened it is lifted up a little from the floor by the sliding upon one another of the inclined helical surfaces; so that although the door may shut very close to the floor, it rises when opened, to a sufficient height above the floor to allow its lower edge to clear the carpet. Another advantage of this kind of hinge is, that the weight of the door acting upon the inclined rubbing surfaces of the hinges, causes it gently to close itself so soon as the hand is removed from it; but as this might in some cases prove inconvenient, a modification is introduced to allow the door to remain open at 90°, or more. In some cases a small spring is attached to hinges of this description, to aid the closing of the door when it has been opened but a little way. Hinges supplied with much more powerful springs are often used for the doors of public offices, where it is desired to render the closing of the door both certain and quick. For such doors hinges which will open in either direction and cause the door to spring back to its original position are often used. Whitechurch's ingenious hinge is an apparatus by which doors or windows may be opened at pleasure either on the right or left hand; or by which, in other words, either edge of the door may be made, at pleasure, the opening edge. A handle is fixed near each side of the door or window, by turning which the required positions of the apparatus are varied at pleasure: the action of this handle being to disconnect or release the door from the style or post near which it is placed, and at the same moment to complete its connection with the opposite style. This apparatus is, however, too complex for general use. Nettlefold's hinge, for the doors of book-cases, has a contrivance by which two adjacent doors opening in contrary directions may be hung without an intervening style: the two doors being connected together by a hinge resembling that by which ordinary doors are hung, and the axis of this hinge being connected with the edge of a thin partition in the book-case by metal brackets above and below the hinge, the space occupied by which is notched or cut out of the edges of the doors. Doors hung in this way fold completely back, and the hinges do not offer the slightest impediment to the removal of the volumes which happen to stand next to the partition, and which, were the doors hung in the usual way, could only be removed by first taking out those which stand adjacent to them. There are many other kinds of hinges of recent introduction, but not calling for special description.

HIPPARAFFIN ($C_{16}H_8NO_2$?), a white crystallisable substance obtained in small quantity by the action of peroxide of lead upon hippuric acid. It is inodorous and tasteless, very soluble in alcohol and ether, and fuses at 390° Fahr.

HIPPODROME (ἱππόδρομος), a large inclosed space appropriated by the ancient Greeks for their horse and chariot races. There appears to have been little substantial difference between the Greek hippodrome and the Roman circus, except that, from the Romans not having been accustomed to allow more than four chariots to compete at once, the circus was made much narrower than the hippodrome. Bearing this distinction in mind, and that the number of chariots which ran necessitated a more complicated arrangement of the *carceres*,—they being placed along a line formed like the prow of a ship with the apex towards the area, and each of the sides 400 feet long,—a sufficiently clear conception of the form and character of the hippodrome will be obtained by a reference to the article CIRCUS. The races will be found described under OLYMPIAN GAMES.

HIPPURATES. [HIPPURIC ACID.]

HIPPURIC ACID ($C_{18}H_8NO_5$, HO) is found in large quantities in the urine of the cow, the horse, and other herbivorous animals. It has also been detected in human urine. It is procured by evaporating the urine of the horse or cow to a small bulk, and acidulating with hydrochloric acid. The mixture deposits brown crystals of hippuric acid, which may be made white by boiling with lime, dissolving the hippurate of lime,[1] and again adding hydrochloric acid, when the pure hippuric acid is thrown down. It forms large semi-transparent four-sided prisms, which are sparingly soluble in cold water, and very soluble in hot water and in alcohol. Under heat it melts and gives off benzoic acid, benzoate of ammonia, and a fragrant oily substance. It forms salts which are soluble and crystallisable.

Concentrated boiling hydrochloric acid converts hippuric acid into benzoic acid and sugar of gelatin.

$$\underbrace{C_{18}H_9NO_6}_{\text{Hippuric acid.}} + 2HO = \underbrace{C_{14}H_6O_4}_{\text{Benzoic acid.}} + \underbrace{C_4H_5NO_4}_{\text{Sugar of gelatin.}}$$

When the salts of hippuric acid are fused with an excess of potash or lime they furnish ammonia and benzole, a reaction which is characteristic of this acid.

The salts of hippuric acid are termed *hippurates*.

HIRCIC ACID. This substance was obtained by Chevreul from the fat of the goat.

To prepare it, the aqueous product of the distillation of the liquid acid separated from the soap of goat's fat is saturated with baryta. After having evaporated the solution, the dry salt is decomposed by dilute sulphuric acid; the hircic acid then floats on the surface of the liquid in the form of an oil.

This acid remains fluid at 32°; it is lighter than water, smells of the goat, is insoluble in water, and forms soluble salts with potash and baryta. It has not been analysed.

HIRCIN, a principle similar to butyrin, which exists in goat's fat and in mutton suet, combined with olein. Its name is derived from *hircus*; and it is obtained from the fat of the goat by a process similar to that by which butyrin is procured, from which it appears to differ by yielding hircic acid, by treatment with the caustic alkalies.

HIRING OF SERVANTS. [SERVANTS.]

HISTORY. The notion that is contained in the word History appears to be often conceived both indistinctly and incompletely. If we trace the word to its original (ἱστορία), which simply means "inquiry" or "search" after facts, and includes the notion of recording them, we obtain a notion which, though distinct as far as it goes, will not enable us to distinguish history from annals [ANNALS]; and if we examine a series of works which bear the name of histories, we shall find many of them deficient in every characteristic which shall be sufficient to distinguish them from bare records of events arranged in chronological order.

In modern times a popular use of the word history has obtained, which may help us in arriving at a more precise notion of what is included in the term. Such expressions as a "History of the Steam-Engine," a "History of Printing," &c., are in common use, and are understood to signify a statement, arranged in chronological order, of the original discovery, and of the various steps and processes by which such discovery has been perfected, and the art, which is the subject-matter of the history, has been brought to its present state. Such a history, then, is nothing more than the explanation of the present condition or state of any given thing, by connecting it with an explanation of all the previous states of the same thing. But whatever propriety there may be in such an application of the word history, it is obvious that a bare narrative, however complete, of the successive mechanical contrivances by which the steam-engine or the printing-machine have advanced from their first rude beginnings to their present perfection, cannot fully satisfy the desire of knowledge when it is once called into action. If the description of such successive mechanical improvements were not connected with social progress, the scientific exhibition of such development, though it might interest the few, would not command the attention nor excite the sympathies of the many. And this leads at once to the conclusion that the various steps and processes by which every art and science has been brought to its present state, cannot be viewed simply by themselves, without relation to each other, and without relation to their effects on the happiness of mankind. All such special history, then, is viewed by us, though often unconsciously, as nothing more than an exhibition of the progress and perfecting of certain elements or ingredients which help to make up that entirety which is called society,—a word which expresses an aggregate of human beings and the infinite relations which unite them.

Another example of history in a limited sense, and one which brings us a step nearer to a proper conception of the subject, is the life of an individual. That branch of the historical art which treats of the life of an individual has long since obtained the specific name of biography. The reason why this species of composition has always given so much pleasure, and often conveyed so much instruction, is clear. To desire to know the past, to ascertain how that which now is became what it is, and the successive steps of its development, is an active principle in our intellectual and moral composition. It is this which stimulates the geologist to his minute investigations into the phenomena which present themselves on the surface of this globe. He labours, if not with the hope of finally attaining a complete view of the successive stages which have determined the actual state of things, yet with the reasonable certainty of learning something, and of being rewarded by a more exact and comprehensive view of the whole present condition of the earth. Such is the interest which some few individuals can create for themselves in branches of investigation which to mankind in general are distasteful or repulsive. But everything which concerns a human being excites the universal sympathies of mankind; and when we hear of those who have greatly dared or suffered, or those who by their talents and virtues have been the benefactors of mankind, or by their vices have inflicted misery on thousands of their own and succeeding generations, we desire to know all the minutest circumstances of the parentage, education, and life of such individuals. We desire to know how they finally became possessed of that character which distinguishes them from other men, and how they finally accomplished that for which their names are remembered. The history of an individual is so far like the history of a nation, that it involves a progress from a beginning to a certain definite point; and though the life of an individual cannot be viewed detached from that of his age and country, it possesses for all the purposes of instruction a sufficient analogy to the life of a nation. The commencement of the national life is generally hidden in the obscurity and the meanness of its origin; its termination, also, is not marked by any event so distinct as that of an individual death, but its condition at any one state, like that of an individual, is to be deduced only from a full comprehension of all the preceding circumstances of its existence.

We may then conclude that the history of any nation is a statement in chronological order of the various actions and events by which the society which constitutes that nation has attained and is in its actual state; meaning by its actual state (so far as such a term is capable of definition), its aggregate means of happiness. But though such a statement as we have just mentioned of actions and events, when they are judiciously arranged, will of itself indicate the general principles which from time to time have more or less affected the condition of society, the purpose of the historian is distinguished from the labour of the annalist by the philosophical character which he gives to his work. It is true that history, even thus viewed, may be written by one man more particularly with reference to one kind of actions and events, and by another man more particularly with reference to another kind; but as the subject of history is the progressive development of society, the historian who best seizes on those things which at each stage characterise this progress, will approach nearest to giving his work a real philosophical character. The religion, the positive morality, the legislation, the education, and the domestic habits of a people, are matters which intimately affect the happiness of a nation. Their progress in the mechanical or other arts is not to be overlooked, for their material prosperity largely influences their moral condition. While, then, the philosophic historian, in tracing the progress of any given society from its origin to its development, omits no event in his series that shall be necessary to link the present with the past, he more particularly directs his attention to the consideration of those civil and religious institutions, and to those popular notions of right and wrong, of virtue and vice, which lie at the bottom of every society that has existed or does exist, however disguised or obscured by the structure which has been reared upon them. To trace to their origin, and to view in their simplest forms, these elements of society,—to seize with precision and completeness their characteristics and their differences,—to follow them in the progress of their development and modification, both as influencing and being influenced by the new elements which from time to time enter into the composition of society, and so to show at each stage of its progress, not only the condition of society, but the causes which determine such condition,—such may be called a philosophic exhibition of history, or, in other words, a determination of the general principles which govern any given society, and the consequences which flow from them.

As this determination of general principles and of their effects forms the scientific part of the subject of history, so the mode of treating and exhibiting such a subject is the artistic part. No exact rules can be laid down for the treatment of history as a branch of art. It may be simply said that while the main object is to instruct, it is also an object to please, independent of the pleasure given by the mere communication of knowledge; that out of the infinite number of events which mark the progress of society, a few are often sufficient for the purpose of the historian, and that in the selection of the most appropriate he will show his judgment and skill; that while he clearly points out those great principles which have had most influence on the condition of society, he will not overload his work with reflections which the matter will suggest to the reader; and he will often not do more than put him in the way of following out a train of thought. His art will often teach him to conceal his purpose of instruction, when his work will not be prejudiced by his apparent forgetfulness of the dignity of his subject.

To enumerate among the historian's qualifications those of industry, integrity, and sound knowledge, or to detail all the qualifications for executing his task in the best possible manner, would be superfluous, if not impertinent. We will, instead of this, briefly consider the value of his labours when complete, and the advantage which his readers will derive from a careful perusal of his work and an examination of the original sources.

It is a common remark that all history is uncertain, and if the remark were true to the full extent, there would be little use in attempting to show the value of that which cannot be known with certainty. But though many events, or rather the circumstances of such events, are uncertain, the most valuable part of history rests upon monuments which have no uncertainty in their character. The positive institutions of every civilised country, its laws and its literature, are facts recorded, which are rich in instruction, independent of their being evidence of an infinite number of other facts of which they are conclusive proof.

The study of these monuments, whether prosecuted under the guidance of a historian who has used them in the construction of his work, or followed out by individuals according to their own judgment and mainly with reference to some special branch of inquiry, is one of the noblest subjects that can engage our attention. Such a study aims at the philosophical exposition of what now is, by reference to what has led to it: it shows what principles lie at the roots of our social system, what they once were, how they have been modified, and what they now are. Knowing what each thing now is, and how it came to be what it is, we are better enabled to form a conjecture of what it will be, and how we may best fashion it to our purposes. Thus, we learn in what circumstances change may be made with advantage; and knowing, from the experience which history teaches, that changes in our social relations become necessary in the course of time, and can neither be resisted with safety nor safely left to be directed by the blind impulse of numbers, we learn how to introduce such changes with the least chance of injury. But such a study, to be prosecuted with success, must be the occupation of a whole life: and if the active man of business into whose hands legislation and administration have been entrusted by choice, or fallen by perverse accident, has neither leisure nor capacity for so extensive a survey, he ought to learn enough to know his incapacity, and to ask counsel of those who are able to give it.

For him who would aspire to the high rank of a reformer of the institutions and the laws of his country, a sound and comprehensive knowledge of the leading notions contained in such institutions and laws, and of their progressive development, is absolutely essential to success in attempting any beneficial change. For in every case of change, the question is not merely, what would be best in the formation of a new society (if such a thing as the formation of a new society could for a moment be supposed), but the question is—what is best in the actual circumstances: and a full or a competent knowledge of actual circumstances must from the very nature of things comprehend a knowledge of previous circumstances.

To those whose business it is to interpret the laws of their country, whether in the way of giving advice or of judicial exposition, a full knowledge of fundamental principles, whether expressed in written laws or resting on recognised customs, is indispensable, in order to enable them to solve the numerous difficulties which attend the complete exposition of rights in a society which has existed for centuries continually progressive in wealth and in numbers. Such an active and living principle can alone maintain the study and the exposition of law in a state of healthy vigour in the midst of the complicated relations of modern society; and such alone can form a sound basis on which to construct a code, if ever the experiment should be found advisable.

What are the advantages of a complete historical study to the philosopher, who would operate upon the popular opinion and impress on his countrymen and the world those principles which he has discovered, or believes, to be the best principles of human action?

While the mass, who are intolerant of the labour of inquiry and reflection, or are deficient in the power of grasping general principles, cling to every existing thing, and every traditional opinion, with the instinct of self-preservation, those who possess, or think they possess (which is the more common case) enlarged philosophical principles, are apt to overlook the conditions which are necessary for their practical application. Thus each actually existing school of philosophy expects to accomplish everything in its own day: it despises the knowledge of the past, and would anticipate the enlarged experience of the future. But the effort to unsettle what has long existed fails before the inert resistance of accumulated ages, embodied in the habits, opinions, and institutions of the actual generation. The anticipation of universal change and complete reformation of social habits and opinions is indulged in for a few short years, sometimes mingled with contempt of those who pertinaciously look behind them, instead of embracing the offered means of perfectibility and throwing away all doubts as to the future. An instructive lesson is all that remains of these brilliant expectations. We learn the folly of wrestling with a power which we have not duly estimated, and of opposing to opinions and habits hardened by the growth of centuries, even the soundest conclusions of our philosophy, when unaided by the experience of history.

HOAR-FROST. The circumstances of terrestrial radiation, chiefly, but not exclusively, nocturnal, under which the aqueous vapour of the atmosphere becomes condensed upon the bodies in contact with it, have already been discussed and explained at some length in the article Dew. If the temperature of those bodies be reduced below the freezing point of water, hoar-frost is produced, the most characteristic form of which differs from dew only "by being frozen in the moment of deposition, and therefore accreting in crystalline spiculæ." But it occasionally happens, as also mentioned already, that after the globules of water constituting dew have been deposited, they are frozen, and become another form of hoar-frost.

In calm weather of the requisite low temperature, without fog, hoar-frost is seen in great perfection, especially in those mornings which are preceded by clear and cold nights, accompanied by a great deposition of moisture, or of what would have been moisture had not the freezing process interfered. It then imparts to trees and shrubs, and out-door objects in general, a great degree of beauty and richness of effect, fringing the leaves of plants with myriads of spiculæ, suspended either parallel to each other, or inclined at various angles, of all lengths, crossing and recrossing, and forming innumerable combinations. In some observations by Mr. Glaisher, first published in the 'Philosophical Transactions' for 1847, and subsequently in the Report of the Council of the British Meteorological Society for 1854, he describes the manner in which these spiculæ were formed on various plants. "The *leaves of the laurel*," he found, "were fringed with spikes one-tenth of an inch in length, and inclined to the leaf both upwards and downwards at an angle of 60°; but none were in the plane of the leaf continued. On the surface of the leaf were spikes down each fibre, one-sixteenth of an inch in length. The leaf itself, in the intermediate spaces, was covered with small white particles. The *leaves of the privet* were richly fringed with spikes for a quarter of an inch within the leaf; the spikes were about a quarter of an inch in length. . . . . *Broom* was most richly encrusted with spikes all round; by far the greater number, and longer than the rest, springing from the sides of each branch. There were comparatively few on the top, and none there were vertical. . . . *Grass* was very beautiful. The blade I found to be covered with white particles, which increased to spikes, becoming longer and larger the further from the root, terminating at the top in a rich circular cluster of spikes, set at all angles from 0° to 60°, and one-tenth of an inch in length. The spikes towards the end of the blade were nearly horizontal, or in the plane of the blade continued. The lower part towards the root was free and untouched by frost." From this latter circumstance, and that previously mentioned of the increase in magnitude of the spikes in proportion to their distance from the root, it may be inferred that the vegetable heat in that region of the plant counteracted the reduction of temperature by radiation, which had occasioned the deposition of hoar-frost on the blades.

Guided as he had been in his experimental researches on terrestrial radiation, and on the deposition of dew, by those previously instituted by Dr. Wells, Mr. Glaisher made a series of experiments also on the formation of hoar-frost on various substances exposed to the atmosphere under the requisite conditions.

Glass, raised one inch high above the ground, was covered with spikes one-sixteenth of an inch in length, and all arranged horizontally at the edges. Glass on grass was free from hoar-frost, doubtless on account of the greater radiating power of the latter, the atmosphere in contact with the glass remaining at a higher temperature.

On metals, such as copper, lead, zinc, tin, iron, &c., there were neither laminæ nor spikes of any kind; but *tin*, raised one inch high, was a little whitened at the edges.

Of three forms of carbon, all powerful radiators, on charcoal and graphite there were spikes in rich clusters, each group radiating from the same point, the spiculæ being generally inclined at all angles; and on lamp-black the spikes were very numerous, being about three-eighths of an inch in thickness, and inclined at an angle of about 30°, and at all azimuths, or in every direction with respect to the cardinal points; each cluster formed a circle, in the centre of which there were no spikes.

On sand there were spikes one-fourth of an inch in length. Chalk was covered with a mass of spikes of the same length. Whiting, which is chalk prepared by grinding, and suspension in water, and subsequent slight consolidation, was covered with rich bunches of spikes three-eighths of an inch in length.

Of cotton wool, every fibre was encrusted with a beautiful fringe of hoar-frost, and there were also a few spikes of ice. Upon flax there were no spikes, it being covered with white round particles (globules of dew frozen?) with small sparkling flakes of ice. Wood was covered with spikes a quarter of an inch in thickness, inclined to the horizon at an angle of 60°, and at all azimuths. Sawdust was very beautifully covered with spiculæ fans, formed by several spikes emanating from the same point at all angles greater than 30° with the horizon. These spikes were connected with each other by lateral spikes or bands, the whole forming the appearance of a fan, whose extent was 120°. Paper was covered with small round particles and a few spikes.

Raw wool was richly clustered on each fibre, so as to be about six times its own size; the spikes were three-fourths of an inch in length, and piled one upon another. Raw wool raised was similarly covered to flax, and displayed only a few spikes running in the direction of its fibres.

Raw silk was covered with spikes one-sixteenth of an inch in length, two of which emanated from the same point, at right angles to the fibre, and whose angle of separation was 30°.

The various modes of aggregation of the minute crystals of ice which constitute hoar-frost, are evidently dependent on differences in the texture, and in the radiating and conducting powers of these materials, and present a field for investigation hitherto little cultivated.

In England generally, as the observations of the late Professor Daniell, confirmed by the researches of Mr. Glaisher, have shown, vegetation is liable to be affected at night, from the influence of radiation, by a temperature below the freezing point of water, every month in the year, even in July and August. This explains the observed fact of the existence of hoar-frost in the early morning, in every season, even in the mildest climates of this country.

But in the Island of Guernsey, in the English Channel, where frost in general is neither frequent nor lasting, hoar-frost, according to Dr. Samuel Elliot Hoskins, F.R.S., is also of rare occurrence, owing partly to the high night temperature, and partly to the constant presence of a breeze, more or less fresh. Neither is hoar-frost general in the island when it does take place, being confined to elevated and bleak situations, and chiefly limited to the months of January and February. Spring vegetation here therefore is rarely checked by that condition which seriously interferes with early crops, even in the mild districts of Devonshire and Cornwall, where the husbandman is often driven to the necessity of protecting early vegetable productions by slight layers of straw, in order that they may not be chilled by their own radiation and the consequent deposition of hoar-frost upon them; or to the more troublesome operation of lighting fires to windward during cold clear nights, in order to produce a warm and virtually cloudy local atmosphere, and so to counteract the radiating process and its consequences.

Ice is also formed on the stems of plants and on certain inorganic bodies, by a process very different from that resulting in the production of hoar-frost, with which, however, it is popularly confounded. The facts respecting it will be stated in another article.

[Dew; Hail; Ice; Meteorology; Radiation of Heat; Snow.]

HOE, HORSE-HOEING. The hoe is an instrument used in gardens and in the fields for loosening the earth, and destroying the weeds between plants. It has various forms. The most common hoe consists of a blade or flat piece of iron, with an eye in which a handle is inserted at an acute angle with the plane of the blade. This hoe is used by striking the edge of it down into the ground, and the earth is moved by drawing the handle towards the workman. Another hoe has the handle at a very obtuse angle, and is used by pushing it forward and cutting off the weeds an inch or less under the surface of the ground. Hoes are made of different sizes and shapes according to the work which is to be done. When the earth is to be stirred between plants which are very near each other, the hoe is narrow and pointed, so that the smallest weed may be taken out close to the growing plant. When the distance is considerable, the hoe is wide, and sometimes compounded of several hoes, in order to stir a greater width of earth at once.

One of the greatest improvements in practical agriculture has been the introduction of the hoe into the field for every kind of crop. Peas and beans were probably the first crops which were sown in rows for the purpose of hoeing the intervals; potatoes, turnips, and carrots were probably the next, and the good effects produced on these crops, by stirring and hoeing the intervals between the plants, have led to the drilling of every other kind of produce which is apt to be injured by weeds. Hand-hoeing not having been found sufficiently expeditious on a large scale, a hoe has been invented of a larger form to be drawn by a horse. The rows have in consequence been widened, and this has introduced the horse-hoeing husbandry, which, half a century ago, was thought so important a discovery as to receive the name of the New Husbandry. The great promoter of this system was Jethro Tull, a gentleman from near Hungerford in Berkshire, who having observed the good effects of stirring the soil around plants, imagined that tillage might supersede all manuring, and that by keeping the soil free from weeds and continually stirred and pulverised, an inexhaustible fertility might be produced, and successive crops of the same kind might be raised without limit. The horse-hoe was the chief agent in this system, which imitated that of alternate crops and fallows; for the intervals between the rows in which the seed was sown were kept in a constant state of tillage, and thus fallowed for the reception of the seed for the next crop. Although these high expectations were not fulfilled, the hoeing of the intervals has caused a very great increase in the produce of the land, especially when united with judicious ploughing and manuring, and a proper succession of crops.

The simple horse-hoe is an instrument with a beam like a plough, and two stilts or handles, but much lighter; in this beam, and in branches from it are inserted, instead of coulters, the ends of iron hoes of the proper breadth to stir the whole surface between the rows. A small wheel is generally added to keep the hoe at a proper depth in the soil.

A horse draws the instrument, which is held and guided like a plough.

From this simple instrument a variety of others have been invented of a more complicated nature, but the object of them all is the same, namely, to stir the ground between the rows, and destroy the weeds as fast as they appear.

This horse-hoe is now chiefly used in the cultivation of peas, beans, potatoes, cabbages, turnips, and carrots.

The effect of hoeing is remarkable in very dry weather. Although the stirring of the soil would seem to extract what little moisture there might be in it, and the weeds wither on its surface, it soon appears that, on the contrary, moisture is attracted or produced, and the plants which drooped before appear refreshed and invigorated. This is probably effected by a chemical action of the air on the vegetable portion of the soil and on the roots of the plants, which have the power of combining the gaseous principles in various ways. Whatever be the mode in which it acts, experience has proved that the more the earth is stirred around plants the better they thrive.

When the intervals are very wide, as is the case where potatoes, turnips, or cabbages grow in rows, a light plough, with one horse, going up and down the intervals, answers the double purpose of a hoe and plough. It stirs the ground to a greater depth, and can be guided nearer to the growing plants than the common horse-hoe. It also turns the soil over into the middle of the interval, from which it may afterwards, when it has been improved by exposure to the air and rains, be thrown back towards the roots and stems of the plants.

The operation of hoeing cannot be performed too soon after the plant has shot out its roots, because the ground may then be stirred very near the young plant without danger, and the roots will spread readily in the newly-stirred soil.

In stiff soils it is often very difficult to use the horse-hoe, owing to the hardness of the surface, which rises in lumps, the very reverse of what is intended; but a little attention to the time of hoeing and to the weather will generally obviate this difficulty. If the soil is bound at the surface, it is a proof that the preceding tillage has not been so perfect as it ought; that the ground has not been stirred to a sufficient depth before winter, nor laid up sufficiently dry, or that it wants underdraining. There are few soils which may not be made mellow and crumbling some time or other in spring, and if the proper time be chosen for the first hoeing, the surface will scarcely ever become so compact as to rise in large clods. In the case of a very tenacious soil the small-spiked roller may be had recourse to, and after using it a few times in dry weather, the surface will be left in a fit state for the common horse-hoe. The method usually adopted in the horse-hoeing husbandry has been taken from the common cultivation of the maize or Indian corn in Lombardy. The rows there are about 27 to 30 inches distant: as soon as the plants are out of the ground, the earth is taken from the plants and laid in a ridge in the centre of the interval; here it is exposed to the sun and rains, which, besides killing the weeds, makes it much finer. In this state it is thrown back upon the plants and laid against the stems, which strike fresh roots into this mellow ground. But this will not be equally proper with all plants and in all soils. Both potatoes and cabbages are much improved by heaping up the loose soil over them; but this is not the case with many other plants. The beet, for example, while it is growing and swelling, is not benefited by having earth thrown round it, for this would induce the root to send out fibres sideways, whereas they should strike downwards in search of moisture. Turnips need not be covered with earth from the intervals, but they may after growth be protected from the frost by this covering. By attending to the growth of any plant we may soon discover when it is advantageous to move the earth from the roots and stems, and when it is best to draw it up around them. With respect to the destruction of weeds, there can be no doubt as to its great importance to all crops. It is generally supposed that every time that wheat is hoed judiciously, more than a bushel per acre is added to the crop, besides the benefit which the land receives by eradicating the weeds. Two or three good hand-hoeings will often so completely clear a field of weeds as to render superfluous the fallow which would otherwise have been necessary, and thus save all the expense of fallowing and the loss of one crop in four or five.

A great oversight is often committed when a field is hoed. The parts nearest to the fences and the sides of the banks, where the plough has not been able to go, are seldom hoed; but these parts become by neglect prolific nurseries of all kinds of weeds, which ripen their seeds, and disseminate them all over the field. No part of the surface should be left unhoed; and when the hoers leave a field, they should be able to defy any one to pick up a growing weed in it.

Those who employ labourers to hoe a field, at a certain price per acre, should be careful to see that the whole ground between the rows and the plants has been stirred; for it is a common trick to throw the earth over the growing weeds, and bury them only, without cutting them up, by which instead of being destroyed, they flourish more vigorously.

The best time for hoeing stiff soils is when they are neither wet nor dry; when the surface is slightly caked, but there is moisture below it, and when the weather is dry after some rain. Light soils can be hoed at any time, and require it oftener than the heavy, especially in showery weather.

A horse-hoe, in which a framework 8 or 10 feet wide supported on large wheels carries twelve to twenty hoes attached to coulters hanging at intervals of a few inches from one another, is used now in the cultivation of drilled corn crops during the earlier stages of their growth. Messrs. Garrett, of Saxmundham, Suffolk, invented an instrument of this kind, which has since been largely copied, in which the width cultivated and number of intervals hoed at once corresponds exactly with the width and rows which had been sown at once by the drill. It thus only needs that the hoe be placed on the exact rows which had been sown at one and the same time by the drill, and any crookedness or unevenness in the row will be followed by the hoes. That unevenness is of course common to all the rows of that width, and it only needs, in guiding the framework of hoes which, rigid together, hang in one piece, that one row be looked to and preserved, and all the others will be safe. Garrett's horse-hoe is now largely used in corn growing districts. One horse will thus cultivate 6 or 8 acres a day, at a cost of not more than 1*s.* an acre, where formerly 4*s.* an acre was expended in hand-hoeing.

HOG. The hog is one of the domestic animals which is most widely dispersed through the world, and yields to no other in its usefulness. It lives and thrives on every kind of food, vegetable or animal. It grazes like the ox, and will even eat hay; and its stomach can digest what few other animals could swallow with impunity. The sow may bear two litters in the year, having from eight to twelve, and even sometimes eighteen or twenty young at a time. No animal converts a given quantity of corn or other nutritive food so soon into fat, or can be made fat on so great a variety of food.

The food of the hog in a wild state is grass, roots, acorns, beech-mast, and wild fruits. He is active and ferocious; and the boar-hunt, from the danger which attends it, is well adapted to excite those who are of a warlike disposition.

There are many varieties of the domestic hog. The brindled hog most nearly resembles the wild species; but although the flesh is savoury, he does not fatten so soon, nor is he so profitable as the more indolent and softer skinned sorts are. The great quality of a hog is his power of digestion; the more rapidly he fattens, and the earlier he can be made to increase in flesh without increasing in bone, the better is the breed. Some of the small hogs which are brought from China are remarkable for this quality, as well as for their prolific nature; and when, by judicious crossing, the size is increased, they are a very profitable breed. The Chinese pig is short in the head, with ears pricked up and pointing backwards, very wide in the cheek, high in the chine, and short in the leg. When a sow of this breed is heavy in pig, her belly generally drags on the ground. The young pigs of the Chinese breed, especially the white variety, are excellent for roasters, at three weeks or a month old. They are small and fat, with little bone, and their skin is very delicate. They also make excellent porkers at about three months old, when kept for some time after weaning on the refuse of the dairy. They may be kept fat from the time they are weaned till they are fit to be killed for bacon; and although they do not come to a great size, they will pay very well for their food if killed at a twelvemonth old.

The breed that is nearest to the Chinese in this country is the Suffolk. They are generally white, with the ears pointed and rather forward. They are broad in the chest and loins, short, and compact: they make fine bacon hogs at twelve or fifteen months old, weighing from twelve to fifteen score when killed. The sucking-pigs and porkers are also very delicate. The Essex breed is mostly black and white. The pure breed however is quite black, and is so nearly allied to the smooth Neapolitan breed, which has scarcely any hair, that we cannot help supposing a consanguinity between them. When crossed with the Neapolitan they produce a breed which fattens at a very early age, and to an astonishing degree.

The Neapolitan hog is black, without any hair, very plump, with pricked ears. No breed can excel it in the aptitude to fatten. The sows often become so fat on very scanty food that they will not breed: they are extremely tender; and if they happen to have litters in winter, it is difficult to save the young pigs from dying in cold nights. A cross of the Neapolitan with some of our hardier breeds greatly improves their usefulness, without injuring their aptitude to fatten: the best cross is with the Berkshire, which is a very well shaped hog, with short legs, small ears, broad chines and loins, and good hams.

From the prolific nature of the hog it is not difficult to select the best individuals to breed from. In every litter there will be pigs better formed than the generality, and by careful selection of these any breed may be soon much improved without crossing; but experience teaches that when the sows and boars are too nearly related, the fecundity gradually diminishes; and by continually breeding from the same stock the sows at last produce only two or three diminutive pigs at a litter. Hence the advantage of frequent crossing. To restore fecundity no breed is so effectual as the Chinese. A breed compounded of the Berkshire, Chinese, and Neapolitan, may, by careful selection, produce every quality which can be desired: numerous litters, early fatting, and fine hogs for bacon at twelve or sixteen months old, are the result of care and judicious breeding.

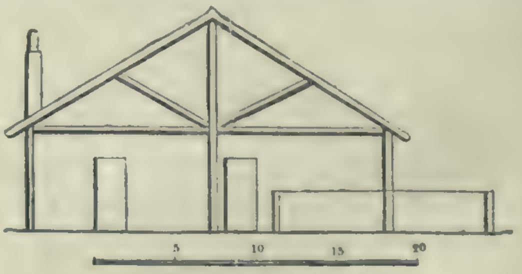
The black hogs are preferred on the whole. They are much less subject to diseases of the skin than the white, and the sun affects them less in summer. For sucking-pigs or porkers many prefer the white, merely for the appearance; for the black skin is in general the finest.

There are some very large breeds, which have been recommended under the idea that in a large hog the bone and offal are less in proportion to the flesh than in a smaller. But these large breeds do not come so soon to maturity. They cannot be profitably put up to fatten till eighteen or twenty months old, or more; and although some of them may make hogs of thirty or forty score when killed, they are so long fatting, and require so much food, that it is very doubtful whether they pay for it as well as the smaller. For delicate bacon the hogs killed at a twelvemonth old, and weighing ten or twelve score, are much preferred; and we are inclined to think that they are most profitable. When hams are the principal object the hogs should be killed before they are so fat as they might be; and the carcase is then cut up and pickled instead of being converted into dry bacon. To keep hogs profitably, a regular system should be pursued both in the breeding and feeding. Proper hogstyes should be constructed, with chambers in which the pigs of different ages and the breeding sows may be kept separate. The food should be prepared for them by boiling or steaming in an apparatus conveniently placed, and the greatest cleanliness and regularity should be maintained. It is a great mistake to suppose that the hog loves dirt. If he can keep himself clean he will do so; and the wallowing in the mud is not from a love of dirt, but from a heat and itching in the skin in warm weather, which is relieved by rolling in the cool mud. If hogs have plenty of clean straw and clean water they never will be dirty, and nothing makes them thrive so quick, or pleases them more, than being washed and curried regularly. If the hogs are not closely confined they will always lay their dung at a distance from the place where they sleep or feed, and in all well constructed styes there should be a small yard to each apartment, in which the hogs can deposit their dung.

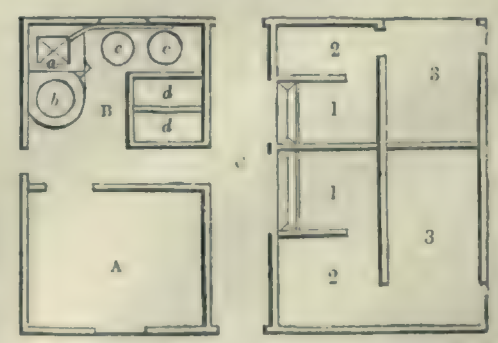
When a sow is near the time of farrowing, which is four months after she has taken the boar, she should be put in a stye by herself, with a moderate quantity of straw, for if there be too great an abundance she is apt to lie down on the young pigs when they bury themselves in the loose straw. Sows, although very careful of their pigs, are very apt to lie on them, especially when any of them are near a wall. To prevent this it is very useful to have a ledge of wood six inches wide and six inches from the ground all round the stye, so that she cannot lie down close to the wall; and if a young pig should be accidentally behind her he can take refuge behind the ledge, and thus escape being lain upon. When no precautions are taken, one-fourth of a litter is often lost in the first day or two after they are born. Some sows have the unnatural propensity of eating their young pigs as soon as they drop; good feeding will prevent this in some measure, but attention at the moment of farrowing is the safest and surest preventive. When once the young pigs have sucked, much of the danger is past.

A sow with many pigs should be well fed; bran and barley-meal with milk or whey is the best food; grains, where they are at hand, are excellent; and it is useful to let the sow go out to graze in a meadow or clover-field for an hour or two every day, shutting up the pigs during that time till they are a fortnight or three weeks old, when they may then accompany the sow. A sow will live many years and bring numerous litters, and the older she is the better nurse she is in general. When a sow has ten or twelve pigs at a litter, and two litters in the year, one in spring and another in autumn, she is too valuable to be killed, and ought to be kept as long as she will breed. But otherwise it is very profitable to let a young sow have a litter at ten months old, and spay her immediately; she will then fatten most readily as soon as the pigs are weaned, and the bacon will be as good as that of a maiden pig. Whenever a sow does not bring a sufficient number of pigs, or is not a good nurse, or has ever eaten any of her pigs, she should be spayed and fattened immediately. The young pigs intended to be kept for stores or for porkers, are castrated or spayed at a month or six weeks old. The males are then called *barrow* pigs, and when fatted make the best bacon. They are usually put up at a twelvemonth old, and fatted in three or four months. At first they have potatoes raw or boiled, mixed with bran, or bean-meal, or they have dry beans and water. After they are half fat they should only have pease-meal or barley-meal and water, unless in a dairy, where they have the skimmed milk or whey. Hogs fattened on potatoes only do not make so good bacon as those which are fatted on corn. This is the reason why the home-cured bacon sells so much dearer than the Irish. When a piece of raw bacon is put into the pot and swells in the boiling, it is a sure sign that the hog has been well fed; if it shrinks, it may be concluded that he has been fattened chiefly on potatoes. The labourers in the country, who live chiefly on bacon, know this well, and always purchase the best fed bacon, even at a much higher price, finding it most economical. Potatoes are an excellent food for store pigs, and may be given boiled and mixed with meal in the early part of the fatting process; but beans and peas make the firmest flesh, and barley meal the sweetest. Before a hog is killed he is usually fed for some time on barley meal and water alone, given as thick as porridge, and very little if any water is given to him. This last rule is often carried to too great an extent. Much water will make the food pass through too rapidly, and it will not be digested, but the hog should never suffer from thirst, or he will not thrive. Before a hog is killed he should be kept without food for twelve hours at least. He may however have water. He should be killed without giving him more pain or causing more struggling than is necessary, by a resolute stab with the knife in the lower part of the neck, where the knife may sever the large artery which comes directly from the heart. The blood should be allowed to flow freely till it is all out of the body. The hog, if intended for salt pork, must then be scalded with water not quite boiling, and well scraped to take off the hair with the cuticle; but for bacon it is best to singe the hair by burning straw over the body, and then scraping the skin. Care must be taken not to allow the skin to be burnt so as to crack. The hog is then hung up, and the entrails taken out. The inside of the body is washed clean with a cloth or sponge dipped in water, that no blood may remain, and the next day the hog is cut up. The head and feet are cut off; the chine is taken out, and the upper part of the ribs, with the backbone, are cut out, leaving as much flesh as possible adhering to the fat outside. The small ends of the ribs remain attached to the bacon.

Hog-stye.—Much of the profit of breeding and fattening hogs depends on the economy of labour in preparing their food. Any place is often thought good enough to lodge a pig in, and a stye is a word synonymous with a filthy place. But in every well arranged farm-yard there should be a convenient place for keeping hogs and feeding them, which may be erected at a small expense, and which will soon repay the outlay. There should be a place to boil and mix the food in, with one or more large coppers and a steaming apparatus. The food should be mixed in square brick tanks sunk in the ground and cemented, that there may be no filtrations. If there is only one tank, there should be a partition in it. From the boiling-house there should be an immediate communication with the feeding-styes, under cover, if possible. Each stye should open into a small yard behind, which should communicate by a door with the principal farm-yard, where the barn is situated in which the corn is thrashed, and be enclosed with a low wall or paling. There should be separate styes for breeding-sows, for porkers, and for fatting hogs. Not more than three or four of the latter should be in one stye. The food should be given in troughs, in a separate compartment from that in which the hogs lie down, and no litter should be allowed there. The floor, which should be of brick or stone, should be frequently washed clean, and the trough should be cleaned out before every meal; any of the food left from the last meal should be taken out and given to the store-pigs. A very convenient contrivance for keeping the troughs clean is to have a flap or door, made with hinges, to hang horizontally over the trough so that it



Elevation and Section.



A, root-house; B, boiling and steaming-house; *a*, steamer; *b*, copper; *c*, *c*, steaming-vessels; *d*, *d*, tanks to mix the food; C, passage to the styes; 1, 1, feeding-rooms; 2, 2, sleeping-rooms; 3, 3, yards.

can swing, and alternately be fastened by a bolt to the inside or outside edge of the trough. When the hogs have fed sufficiently the door is swung back and the trough is easily cleaned out. It remains so till feeding time, when the food is poured in, without any impediment from the greedy hogs, who cannot get at it till the door is swung back. This simple contrivance saves a great deal of trouble, and is easily adapted to any common stye. It is a great advantage to be able to inspect the styes without going into them, and this is effected by placing them under a common roof, which may conveniently be a lean-to to the boiling-house or any other building, with a passage between them.

The preceding figure will best explain this, and show its superiority over common styes.

HOGSHEAD, an ancient measure of liquids, which, not being mentioned in the act 5 Geo. IV., cannot now be considered as having any legal existence.

The hogshead of wine was 2 wine barrels, or 63 old wine gallons; the London hogshead of ale [Barrel] was 1½ ale barrels, or 48 ale gallons; the London hogshead of beer was 1½ beer barrels, or 54 beer gallons; and the ale and beer hogshead for the rest of England was 1½ barrels, or 51 gallons.

All Excise measurements being now made in gallons, the term hogshead remains in use only as the name of a large cask.

HOLLANDS. [Geneva.]

HOLY ORDERS. [Ordination.]

HOMAGE, an incident of tenure which is now abolished by 12 Car. II., c. 24. [Feudal System.] The word, according to Sir Edward Coke, is derived from homo, because when the tenant did his service to the lord, he said, "I become your man," &c.

Homage, according to the old English law writers, was of three kinds: by ligeance, by reason of tenure, and ancestral; the distinction between which is not necessary to state here: the whole subject, which is now merely matter of curiosity, is explained in 'Coke upon Litt.,' p. 64, and following pages.

The copyholders, or tenants who attend to do their duty in a court baron, are called *the homage*.

HOMBERG'S PHOSPHORUS. [Calcium; *Chlorine and Calcium.*]

HOMESTEAD. There is in most districts of the country a great difference between what is required as farm buildings by the intelligent farmer and what is supplied to him by the landowner. Every writer on agriculture has described what is wanted, but it is only here and there that you find specimens which come up to their ideal. Thus, Mr. Hewitt Davis, ('Practical Essays,') wrote many years ago the following description of a homestead:—

"On a well-arranged farm, the following details will have been attended to, namely:

"1st. The situation of the homestead will be central, and hard roads will have been made to afford free communication between it and all parts of the farm.

"2nd. The farmer's residence will have been so placed that he may see what is doing at the homestead, and have a constant eye on the labourers, the live stock, and property on the premises.

"3rd. The yards will be so protected by the stables, cattle-houses, and barns, that the stock will be sheltered from the east, north, and west quarters, and open only to the south, and so formed that the manure will be collected with least possible waste.

"4th. The barns will extend east and west, so that the sun at noon may shine on the barn floor, and their south side may form shelter hovels for the cattle to lie under.

"5th. The open cattle-sheds and pig-sties will face the south or west, so that the sun may shine into them, and the stock may lie dry and sheltered from the colder winds.

"6th. The rick-yard will be so situated as to have a quick and convenient connection with the barns, and be provided with rick-stands on pillars best adapted for ventilation and protection of the corn from vermin.

"7th. Tanks will have been made for the collection and preservation of the drainage from the stables, cattle-sheds, and yards.

"8th. A supply of water will have been provided, in convenient situations, for the ready and constant use of the animals.

"9th. Cottages will have been erected on the farm to secure a certain amount of labour at all seasons, and in situations where the labourers will lose little time in going to and returning from their labours, and may assist in the preservation of the property of the farm."

These memoranda will, with few exceptions, serve as a guide in almost every circumstance to what is wanted as a homestead. The tendency at present is to do away with barns, and to cover a given space of ground with shedding, dividing out the space thus sheltered into yards, or stalls, or boxes, according to convenience; but the references to position, aspect, accommodation, tanks, water, cottages, will be generally allowed as applicable everywhere. In illustration of the completer equipment which one sometimes meets with now on first-class farms, the following paragraphs are given as descriptive of the Coleshill farmery on Earl Radnor's home farm, the Englefield farmery on Mr. Benyon's home farm, and the Haineshill farmery on Mr. Garth's home farm, all in Berkshire. They are all more or less on the new system of a roof over the whole quadrangle on which the buildings stand.

1. *Coleshill Farmery.*—On entering the buildings, and the adjoining rick- and timber-yards, which you do at the east end, you find yourself in the barn, and in the upper story of it; for it is two stories high, the upper story being on a level with the rick-yard, and the lower on a level with the floors of the stables, cattle-sheds, and yards. This difference in the levels is caused by the site being on a declivity, which has been most judiciously taken advantage of, and by a little extra labour divided into two steps or flats, each with a very slight incline downwards, towards the west. In this upper story of the barn is placed part of the machinery connected with threshing and dressing the corn, weighing, and sacking it; also a mill, with a pair of French stones, for grinding wheat or other grain, either into fine flour, or for merely crushing it or kibbing it. There is, too, a mill for grinding linseed. Opening from this large floor is, on one side, a spacious granary, from which the corn, when dressed and sacked, can be let down, through a trap-door, by a chain and pulley into the waggons, to be conveyed away when sold. It opens also into the engine-house, and into a large loft for storing wool or anything else that requires to be kept dry. The threshing-machine, which, with all the other machinery, mills, chaff-cutters, &c., is driven by a steam-engine of 7-horse power, is placed on the ground adjoining to and on the same level with the upper floor of the barn, as is also a circular saw for cutting out rough stuff, which is likewise worked by the engine. All this machinery, including the steam-engine, was made and erected by Messrs. Clayton and Shuttleworth, of Lincoln. It is composed of various machines by which the grain is threshed, dressed, deposited in sacks, and weighed, ready for market, at one operation, without any intervention of manual labour. There is also a mill on an improved principle for grinding corn for cattle; also a chaff-cutter; a mill for bruising oats and linseed; a saw-bench with circular saw, &c., in the carpenter's shed: all of which are driven by a 7-horse power portable steam-engine outside the barn wall, which communicates the power to a line of shafting extending across the barn, from which the various machines are driven by leather bands. The straw passes down from the threshing-machine, on a sort of riddling screen, to the ground floor below (where the chaff-cutter is placed), either to be converted into chaff or to be stored away in the straw-house. Following it by a staircase, which leads down to the ground floor, the second flat or step of the area of the premises, you find yourself in a commodious building, with doors north and south large enough for a loaded waggon to pass through them. This building is appropriated for receiving the caving, chaff, and straw when cut for litter, being divided into separate rooms; the north end being reserved for the purpose of storing roots which are thrown in from the upper level through a shute provided for that purpose. The adjoining rooms are fitted up with various apparatus for steaming and preparing food for pigs and cattle, and comprise, as well, vaults for skim-milk, wash, &c., and a slaughter-house. On leaving this building by the south door, you enter a court in which, on your left hand, are the riding-horse stables, coach-house, harness-house, &c.; and above, and adjacent to them, the steward's office, room for reckoning with the men, &c. On your right hand is the building containing the boxes and stalls for the dairy cows, and the yards and sheds for these cows and their offspring, and for young stock. On leaving this building by the north door, another court is entered, which is surrounded by sheds for carts, ploughs, and other implements; by the cart-horse stables, harness-houses, &c.; and by the yards attached to some of the boxes for fatting cattle.

Returning to the centre of this building,—that is, to the spot, or near to it, where the straw from the threshing-machine comes out from the apparatus above,—and turning your face to the west, you look down a long vista, flanked on one side by the piggeries, and on the other by boxes for fatting cattle. The roof is of slate, with skylights, glazed with rough plate-glass, and open at the sides, which are fitted with ventilators. The roofs of the other avenues and of those parts of the building where the stock is kept confined are lighted and ventilated in a similar manner; thus every part of the place wears a light and cheerful appearance, and as there is free escape for all impure exhalations from the cattle and the litter, and as powdered gypsum is scattered about when and wherever necessary, the building is entirely free from any unpleasant smell. In the centre of this covered path, or main avenue, is a tramway which runs down to the tanks, and is to be continued on into the sheep-house, which is placed at the bottom, at the extreme west end. On passing along about two-thirds of this avenue, you come to a turn-table on the tram-way, the line being intersected here, at a right angle, by another avenue or transept, on which also a tramway is laid, which runs across the building from north to south, and on each side of which are cattle-boxes—the south end of it running into the building containing the boxes and stalls for the dairy cows. Leaving the main avenue at its western end (at the tanks), you cross a yard and enter the sheep-house, a spacious building at the extreme west of the premises, with an open railed floor, and pits underneath for the manure. Here there is ample room for about 400 sheep, for 250 or 300 ewes, and for 100 fat sheep, which latter are tied up at rack and manger. Right and left of this sheep-house and of the open yard between it and the tanks and manure shed, and occupying the south-west and the north-west corners or wings of the premises, are sheds and yards for young cattle, for 30 head of which there is ample room.

Returning from this point, and reaching the turn-table, you have, right and left, and before you, the cattle-boxes, 44 in number, intended for the use of 30 large beasts, each occupying an entire box, and 28 young beasts, standing two in a box. Turning to the right, you pass along the south branch of the transept, with cattle-boxes on each side of you, till you enter the cow-house, which occupies the centre portion of the south side of the premises. Here is room provided for 30 dairy cows,—20 in stalls, tied up, and boxes for 10, intended for the calving cows and their offspring. Attached to this department is the cow-yard, constructed to accommodate 14 cows, with room for 20 calves, on stages and boxes. There is also provision made for tying up 12 beasts, on the old stall-system, and for four bulls—two old and two young ones. On turning to your left, at the turn-table, on coming away from the sheep-house, you pass between the other end of the double row of cattle-boxes, and come out into the yard in front of the row of buildings composing the cart-horse stable (for 12 horses, with two loose boxes), harness-houses, sheds for implements, &c. &c.; these occupy one side, the north side of the yard; the west side being occupied by sheds and inclosed yards for young stock, colts, and for other purposes.

The piggeries are placed, as stated at the commencement of the description of the part of the buildings devoted to the reception of cattle, on your left hand as you proceed westward down the main avenue. They contain boxes walled in, for eight breeding sows and their young, for two boars, and for a score of fat pigs; each box having an inner and an outer compartment, or rather having an open yard attached to it, so that the inmates can enjoy themselves in the open air or under cover at will.

For this account of the Coleshill buildings we are indebted to the 'Wiltshire Independent.'

2. *The Englefield farmery.*—The buildings are centrally placed. They consist first of a block, about 50 feet by 100 feet, covered in by a double span roof, under which are 42 boxes—six single rows of seven each—the rows being separated alternately by three narrow gangways for feeding, and two wider gangways for carts entering to remove the dung. Each box has a manger for roots and hay and a trough for water. They are separated by rough paling, and the cattle are hindered from dirtying these troughs by a loose pole which they have to lift before they can get at their manger.

Another block of buildings of the same length includes threshing machines, granary, root-house, chaff-house, steam-house, and steam power (a fixed 10-horse engine consuming 8 cwt. a day of coals, and worked now about three days in the week). Between the two the space is roofed over and occupied as a straw house. The steam power is conveyed by strap to a longitudinal shaft upstairs, from which straps on pulleys carry it to the threshing-machine, turnip-cutter, two pairs of mill stones, two chaff-cutters, cake-crusher, and corn-bruiser.

The steam power is used to cut the roots for two days' supply by means of Samuelson's largest Banbury cutter, and to cut hay chaff at the rate of 5 tons in a day, two men feeding the chaff-cutter, and to crush oats and crack beans by Turner's capital machine for the purpose—all at one and the same time.

On the south side of this block of cattle boxes is a shed for implements. On the west side is a range of stables, lofty and airy, with no particular nicety, but great convenience, of internal arrangement, and on the other side as a lean-to there are shedding and yards for the calves, of which 50 or 60 are kept in three divisions, provided with racks for straw and mangers for the roots, and chaff, and cake. North of the threshing machinery and barns are six long rows of open roofing for storing away the corn. The implement shed, barns, straw house, granaries, and corn-shed thus succeed one another as you go northwards. East of this range is a cow byre, nag stalls, slaughter-houses, poultry-house, &c., on two sides of a square, thus sheltering a yard for cows and calves from the north and east, and lying alongside of the cattle boxes, and another square of pigsties and yards lying alongside of the granaries and threshing machinery. The corresponding space eastward of the rows of corn sheds remains to be occupied by sheds and yards for cows, if it should be resolved to establish a herd of short-horns. The threshing machinery was erected by Clayton & Shuttleworth, of Lincoln. The buildings were planned by Mr. Benyon and his steward, and erected by the workmen of the estate at a cost of about 3000*l*.

3. *The Haineshill farmery* has been erected from the plans of Messrs. Beadel and Chancellor, London, and their leading feature—extensive yards under lofty roofing—is more or less carried out at all the other homesteads which those gentlemen have erected on the estate. The main block of buildings occupies a ground plan of about 140 feet by 100. There is a lofty range on the long side, which runs north and south, and from the middle of this projects a shorter piece of the same height towards the east, while the main block is an extension for about 100 feet westwards of the same roof of its full length, generally, however, of a somewhat lower elevation. The lofty range includes in its centre a very complete threshing machinery, worked by a steam-engine of 8-horse power—all erected by Messrs. Ransome, of Ipswich. On the one side of this centre-piece lie the granaries above and cattle food stores with chaff house below; and on the other side lie hay and chaffing apparatus above and roots below. The hay is put in, from the cart or waggon outside, on the level of the upper floor, the roots are thrown in from the ground floor below. The corn to be threshed is thrown in on the upper floor at the end of the arm of the buildings which projects eastward; the ground floor of that piece being occupied by carpenters' shops. The corn fed into the machine on the upper floor passes downwards, the chaff is blown out below; the straw reappears, being lifted by the clever elevating shaker employed by Messrs. Ransome in their fixed barn machinery; and the corn being winnowed on its descent is brought upwards in elevators and passed through another winnower before it reaches the separators, from which it is delivered in sacks on the granary level. These are at once wheeled off to the stores, while the straw is carried away and stored on a floor on the same level, which extends under the higher part of the roof right over the covered yard below, from which it is thrown down for the supply of the yards.

From this floor you look down upon the yard below, and you see that the space is divided by three parallel gangways, extending westward from the north and south line of stores of chaff and roots. parallel with the sides of the yard. The two side gangways are about 4 or 5 yards from the side walls, the middle gangway extends down the centre of the intervening space. As you walk down one of these side gangways, you have on either hand the boxes in which the farm horses are kept solitarily, most complete in all their equipment with manger, water-trough, &c., only boarded up so high as to make it a case of complete solitary confinement except in so far as each has a look out on the gangway. As you walk down the other side gangway you have on one hand first boxes for cows, then little yards for sows with litters. On the other hand you have three yards each for six or eight cattle, either dairy stock, fatting beasts, or young and growing heifers and steers. The central gangway under the straw floor from which you see all this, has upon one hand a long range of sparred flooring divided into yards for ten or a dozen sheep each, and containing in all about three-score useful Hampshire Down tegs, evidently in thriving condition. On the other hand, and between you and the horse boxes, lies another series of yards for fatting cattle. The yards are sheltered on the north and east by the highest portion of the erection, and being also walled up on the sides to the roof, they are left for the most part open on the western side. The ridge lines of the roof are glass, and there is ample window room for light, so that light and ventilation are provided along with perfect shelter.

Apart from this main block of buildings lie the steward's house and out-houses, including an exceedingly neatly and even elegantly equipped dairy, a bake-house, slaughter-house, poultry-house and poultry yard.

The western and *open* side of the building presents a very tasteful elevation towards the mansion, which, at the distance of half a mile or more, presents its old Elizabethan gables amidst the wooded park.

On the same estate there are other good homesteads. Those at Hinton for instance, while evidently on a similar plan with that of the home premises at Haineshill, though on a smaller scale, are in some of their features superior. They, like the Haineshill ones, include yards open to the south sheltered by a lofty roof supported on slender iron columns and surrounded by a wall on the north side, and by a range of barns on the west, and of granaries, root-stores, chaff house, and stables on the east. The stables are thus open to the outer air, though well under the shelter of the roof, and the horses are arranged in pair stalls with swinging divisions. The central yard is surrounded by a gangway and includes divisions for cows, for fatting cattle, for calves and yearlings, with pens for swine. The floor is asphalte.

In addition to these descriptive notices, it must suffice to say, that the cost of good buildings is well repaid by the increased annual value of the estate. Shelter for live stock, and safety for produce, and for both cattle and implements, are always worth paying for; and the tenant of good land will not grudge as additional rent, a good per centage on the landlord's outlay in providing him with the necessary buildings.

HOMICIDE, in the English law, signifies the killing of one man by another. Homicide is of three kinds: justifiable, excusable, and felonious. Justifiable homicide is when the death is caused by the performance of an act of unavoidable necessity, where no shadow of blame can be attached to the party killing, as soldiers in action, persons defending their own lives, &c. Excusable homicide is of two kinds, by misadventure, and in self-defence; the first is where a man doing a lawful act, and using proper precautions, unfortunately kills another; the second, where a person in defending himself from an assault of a less serious nature than the second instance of justifiable homicide before mentioned, kills the offender; and this it is often difficult to distinguish from manslaughter, in the legal sense of the word.

Felonious homicide is the offence of murder; for the legal definition of which crime see MURDER.

HOMILY (ὁμιλία), in ecclesiastical writers, is a familiar discourse on a religious subject. In the earliest ages of the church the words *sermon* (λόγος) and *homily* appear to have been used indifferently; but Photius distinguishes the homily from the sermon, as being a familiar conversation, in which the preacher and people interrogated each other.

All the homilies of the Greek and Latin fathers were composed by bishops, for before the 5th century none but bishops were allowed to preach. We have good specimens of this sort of composition extant among the works of Chrysostom, Gregory, and other fathers. The

'Clementine Homilies' are supposed by Le Clerc to have been forge by an Ebionite in the 2nd century. (Lardner's 'Credibility,' pt. i, c. 29.)

In modern use the term "homily" is applied to a discourse read out of a book, and not composed by the preacher.

In the 8th century a collection of homilies was compiled from the writings of the fathers by Paul the deacon and Alcuin, at the command of Charlemagne. This collection is called the 'Homiliarium of Charlemagne.'

At the period of the Reformation in England two books of homilies were published by authority, in order to ensure uniformity of doctrine and to supply the defects of some of the clergy. The first book was published in 1547, and consists of twelve homilies, many of which are ascribed to Cranmer, and others to Latimer, Ridley, and Pilkington; the second, containing twenty-one homilies, supposed to be written by Bishop Jewell, was published in 1562, though composed earlier. They were appointed to be read in churches every Sunday, unless there were a sermon. These homilies are recommended by the 35th Article of the Church of England as "containing a godly and wholesome doctrine;" a list of them is given in the Articles appended to most Prayer Books; many of them are divided, so that in the whole there are forty-four discourses. Of the first book, which is less known, the following are the heads:—

1. A fruitful exhortation to the Reading and Knowledge of Holy Scripture; in two parts.
2. On the Misery of Mankind, and of his Condemnation to Death through everlasting, by his own Sin; two parts.
3. On the Salvation of Mankind, by only Christ our Saviour, from Sin and Death everlasting; three parts.
4. A short Declaration of the true, lively, and Christian Faith; three parts.
5. Of Good Works annexed unto Faith; three parts.
6. Of Christian Love and Charity; two parts.
7. Against Swearing and Perjury; two parts.
8. How dangerous a thing it is to fall from God; two parts.
9. An Exhortation against the Fear of Death; three parts.
10. Concerning good Order and Obedience to Rulers and Magistrates; three parts.
11. Against Whoredom and Uncleanness; three parts.
12. Against Contention and Brawling; three parts.

HOMŒOPATHY, the art of curing founded on resemblances, expressed in the Latin expression "similia similibus curantur." It is derived from the two Greek words "*ὅμοιος*" "similar," and "*πάθος*," "feeling" or sensation, and hence a condition of body, such as that of disease. According to this law, disease is cured by remedies which produce upon a healthy person effects *similar* to the symptoms of the complaint under which the patient suffers.

This system of medicine stands in direct contradistinction to that founded upon the principle of treating diseases by their opposites, "contraria contrariis curantur," which has served more or less as a guiding law since the time of Galen. To this last method the disciples of the new school have given the name of Allopathy, from the two Greek words "*ἄλλος*," "other," and "*πάθος*," "condition." This distinctive nomenclature will be adopted in this article as a matter of convenience, and to avoid circumlocution. The arguments adduced in support of the truth of the homœopathic law seem principally drawn from three sources, namely, from popular experience, from observations upon the effects of medicinal agents recorded in the works of eminent medical men of different schools and various epochs, and from experiments upon healthy individuals made by the founder of the system and his disciples upon themselves.

1st. Popular experience has proved that the safest manner of restoring the circulation of a frozen limb is to rub it with snow (similia similibus); warm applications, according to the evidences of the same experience, would cause the destruction of the part affected (contraria contrariis).

Again, severe burns are most quickly cured by the use of heated spirits of wine or oil of turpentine, which excite a very similar sensation, although in a greatly modified degree (similia similibus). Cold applications, although they give temporary relief, are, as is well known, generally followed by increased inflammation and severe after-suffering (contraria contrariis), as corroborated by the evidence of John Hunter, Kentish, Sydenham, and other medical names of high repute.

The homœopathists also insist that the acknowledged efficacy of Jenner's great discovery is a powerful argument of the truth of the homœopathic law, since by producing a similar disease an almost perfect immunity from attacks of the small-pox is obtained.

2nd. They endeavour to show by a number of observations collected from the works of different medical allopathic authors, that many drugs recorded by them as curative in different forms of disease were observed by others, also allopathists, to produce effects closely resembling the symptoms of those very forms of disease, or in other words, that they acted upon the principle, similia similibus: an instance or two will be sufficient illustration. The English sweating sickness, which committed such ravages in the year 1485, and for some time baffled the physicians, yielded, according to Willis, to sudorifics; and it is upon record that after the adoption of this mode of treatment very few died of it. Opium in general causes extreme drowsiness, heavy and deep sleep; and it has, according to the testimony of many allopathic physicians, proved curative in diseases characterised by similar symptoms. Moreover, it is asserted by the homœopathists that all the remedies acknowledged as specifics by the medical profession, of whatever school, act upon this law; for instance, they maintain that Peruvian bark produces medicinal symptoms closely analogous to those of marsh fever, and that the well-known efficacy of mercury in syphilitic complaints, and of sulphur in various forms of cutaneous disease, is attributable to the same power (similia similibus), and as above stated, that the action of vaccine matter, as a prophylactic or preventive medicine against small-pox, depends upon the same law.

3rd. Dr. Samuel Hahnemann, the founder of this system of medicine, being struck, as noticed in his life [HAHNEMANN in BIOG. DIV.], with the close analogy between the symptoms produced by Peruvian bark and those of the forms of disease for which it was considered a specific, and having obtained similar results from other medicines tried upon his own person, was led to the discovery of the homœopathic law; and he, believing that the mode of operation of all remedial agents was in perfect harmony with this principle, by repeated experiments upon himself and some medical friends, converted to his opinions, first determined their direct action and then employed them in disease. The practical results obtained by himself and the physicians of his school are appealed to by them as a further confirmation of the truth of their fundamental law.

The extremely minute quantities in which the remedies are administered, seem to form a marked difference between the homœopathic and all other schools of medicine. The homœopathists however assert that this is merely a point of practice to be determined by the physician at the bedside of his patient, and that in the application of the homœopathic principle to the treatment of disease, it was soon found that remedial agents given in the doses usually employed, acted too energetically upon a frame already predisposed to their influence by the affinity existing between their medicinal effects and the morbid signs of the disease; and hence a gradual diminution was made in the quantity of the medicine exhibited, in order to approximate to that amount which might exert its full curative power without aggravating the sufferings of the patient by an excess of medicinal action. The result has been, the general adoption among homœopathists of the minute doses at present in use.

Homœopathy numbers in its ranks many medical men who had obtained high repute and professional eminence in the other systems, before they embraced the principles of homœopathy, and seems to be more or less diffused in all parts of the world, if we may form any opinion from its literature, which comprises medical works in German, Italian, English, French, Swedish, Russian, Spanish, Latin, and Portuguese. The system has also adherents in North and South America and Asia. The great bulk however of the medical profession are more or less opposed to its adoption. This has arisen from the fact, that with an increased knowledge of disease and the action of medicines, there has been a tendency amongst medical men to discard all general theories of the nature of disease and the action of medicines. Although it is assumed by writers on homœopathy, that there is an allopathic theory, no well-educated medical man would adopt any such theory. The facts of homœopathic writers will stand even should their theory be forgotten; and it is to be regretted that the founder of this system, and his followers, have sought to impress their views rather as members of a sect than as men of science. The opposition which their views have experienced has been mainly due to this sectarian tendency. The question between homœopathists and other members of the medical profession, is rather social than scientific, a question rather of medical ethics, than of the interpretation of facts.

HOMOGE'NEOUS and **HETEROGE'NEOUS**, terms applied in mathematical language to expressions which have or have not the same number of factors of a given sort. Thus, with respect to x and y, $a x^2 + b x y + c x^2$ is homogeneous, but $a x^2 + b y$ is heterogeneous.

HOMOLACTIC ACID ($C_4H_4O_6$). A peculiar organic acid described by M. Cloëy as being produced in the manufacture of fulminating mercury. It is a colourless syrupy liquid of specific gravity 1·197, and is isomeric with *glycollic acid*. M. Dessaignes regards homolactic acid as impure glycollic acid.

HOMOLOGUES. [HOMOLOGOUS SERIES.]

HOMO'LOGOUS, a term applied in Euclid to those magnitudes which are both antecedents in a proportion, or which are both consequents. But when the four proportional magnitudes are all of one kind, the right of alternation empowers us to make and call any two terms homologous, of which one is an extreme and the other a mean.

HOMOLOGOUS SERIES. When the formulæ of the individual members of certain families of organic compounds are compared, it is found that these formulæ bear a very simple relation to each other, and that the individual members of each family differ in composition by two equivalents of carbon and two of hydrogen, or by some multiple of this number. The family of organic bodies to which common alcohol belongs affords an illustration of this graduated composition, as will be seen from the following table of the formulæ of these bodies:—

Methylic alcohol	$C_2H_4O_2$
Vinic alcohol (spirit of wine)	$C_4H_6O_2$
Propylic alcohol	$C_6H_8O_2$

Butylic alcohol	$C_8H_{10}O_2$
Amylic alcohol	$C_{10}H_{12}O_2$
Hexylic alcohol	$C_{12}H_{14}O_2$
Caprylic alcohol	$C_{16}H_{18}O_2$
Cetylic alcohol	$C_{32}H_{34}O_2$
Cerylic alcohol	$C_{54}H_{56}O_2$
Melissic alcohol	$C_{60}H_{62}O_2$

Such a family of organic bodies is termed a *homologous series*, and the members or terms composing it are said to be *homologues*, or homologous with each other. Whenever the formulæ of two neighbouring bodies in a homologous series differ from each other by a multiple of C_2H_2, a number of intermediate bodies, sufficient to fill up the missing step or steps in the graduation, must exist, and their subsequent discovery may be confidently predicted. Thus for many years the vinic and amylic alcohols in the above table stood next to each other, but the existence of the intermediate propylic and butylic alcohols was never doubted, although their actual discovery only took place very recently.

The following are the principal homologous series, or groups of series, which will be found described under their respective heads:—

Alcohols.
Anhydrides.
Ethers.
Haloid ethers.
Ethereal salts.
Organic radicals.
Hydrides of organic radicals.
Ketones.
Fatty acids.
Organic bases.
Organometallic bodies.
Amides.

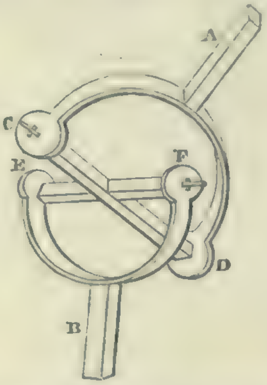
HONEY is a fluid or semi-fluid substance, the materials of which are collected by different kinds of bees, in Europe chiefly by the *apis mellifica*, or hive-bee, and solely by the neuter or working bees, from the nectariferous glands in the cup or chalice of flowers. It cannot be said to be a purely vegetable production, for after being collected by the proboscis of the insect it is transmitted to that distension of the œsophagus termed the crop, sucking-stomach, or honey-bag, where it is elaborated, and again disgorged, to be deposited in the cell of the honey-comb. It undergoes less change when the bees are very young, remaining nearly white, and is then denominated *virgin* honey. At all times it retains qualities derived from the kind of plant whence it has been procured, as is manifest not only by the peculiar odour of the honey, but by the effects which follow the use of honey obtained from certain plants, such as the Azalea, rhododendron, kalmia, &c., which yield a honey frequently poisonous, while that from the genus *Erica* (termed heather-honey), and most *labiate* plants, is wholesome. The soldiers of Xenophon, during the retreat of the Ten Thousand, suffered severely from partaking of honey collected by bees from the Azalea pontica near Trebizond.

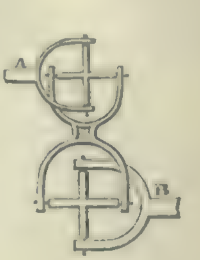
The honey of the common bee is at first generally white, inclining to yellow, but by age it becomes of a deeper colour and greater consistence, and of a more acrid taste. The honey of Surinam and Cayenne, collected by the *apis amalthea*, is red. The *apis unicolor* of Madagascar produces a greenish honey collected from the Mimosa heterophylla and Weinmannia glabra, of the most exquisite flavour. Honey is of different degrees of consistence: that of Mahon, of Hymettus, and of the Bermudas, is liquid; that of England is more or less disposed to become nearly solid.

Honey is sweet, faintly aromatic, granular, soluble in water, and capable of undergoing the vinous fermentation, and so yielding an intoxicating drink called hydromel, metheglin, or mead. Honey consists of an uncrystallisable portion, and a portion which crystallises in very white grains. The former is soluble in alcohol, the latter not, and is regarded as a sort of *Mannite*, or manna sugar, which, by the action of nitric acid, can be converted into oxalic acid, like the sugar of the sugar-cane. When old it probably contains some free acid. Honey is sometimes adulterated with flour, from which and other impurities it may be freed by diffusing it through cold water, or by striking the blue colour, indicative of starch, on adding iodine. Honey is certainly nutritive, but it cannot be employed to any great extent, since, if taken in considerable quantity, it excites the action of the bowels, and is gently laxative. Its effects in this way will be greater in proportion to its age and acridity, and less or scarcely appreciable if largely diluted with water. In this last state it is rather demulcent, emollient, and refrigerant, and hence forms a good drink in fever and other inflammatory complaints, but it should not be taken if there be much gastric or intestinal irritation. It is used likewise in catarrhs, and when drunk warm is considered to be expectorant. Along with vinegar it forms a good gargle in slight cases of sore throat, and combined with borax a most efficacious application in aphthæ of the mouth and throat. Owing to idiosyncracy in some individuals, honey causes great uneasiness, or even severe suffering, but it is most likely that such cases originate in the kind of plant from which the honey is collected, or in the measures used to destroy the bees. Smoking them with sulphur must be hurtful, from forming sulphurous acid gas, which may be absorbed by the honey. Humanity as well as economy demands that other means should be employed to procure the honey without sacrificing the life of the industrious insects which collect it. The fungus known as puff-ball, or Lycoperdon Bouesta, when smoked under the hive, stupefies the bees, as chloroform does men, so that the honey can be removed while they are insensible.

HONEY-TEA is nowise related to the foregoing. At the Cape of Good Hope this name is given to the infusion of the leaves and flowers of plants, growing abundantly on the sides of hills formed of variegated sandstone. These leaves and flowers are collected in great quantity by the poorer classes as a substitute for green tea. They are beneficial in diseases of the chest, which are, however, rare at the Cape. The plants are *Cyclopia galioides* (*D. C. the Aspalathus callosa*, Burn's 'Flora Cap.'); *C. genestoides, Goniphlobium maculatum* (Andrew's 'Bot. Repos').

HOOKE'S JOINT. Hooke's universal joint is a method of connecting two axes, the directions of which meet in a point, so as to transfer rotation from one axis to the other. The first figure represents the *single universal joint* in which A and B are the shafts between which the rotation is transmitted: C D, E F, is a cross the ends of which turn freely in bushes formed in the extremities of two diameters of semicircles in which the shafts terminate. If the shaft A be made to revolve B will evidently revolve also. If however the angle under the directions of the shafts be less than 140°, the motion will not be transmitted. In such case the *double universal joint* represented in the second figure must be used: this has two crosses, the extremities of which move on pivots like the former. These joints may be formed with a hoop or a solid ball instead of a cross, in which case four pins project at four equidistant points, so as to divide the circle in four equal arches, and the pins play in the bushes of the semicircles as in those of the cross.





The universal joint is much used in adjusting the position of a large telescope, where the observer has to turn endless screws or wheels, in a position inaccessible while the eye is being directed through the tube. This joint is also used in cotton and other mills where shafts are carried to a great distance from the prime mover, and it is an advantage to divide the shaft into convenient lengths, with a joint of this kind connecting them. The principle of Hooke's joint may be studied in the limbs of crustaceous animals and insects.

HOOPING-COUGH, or WHOOPING-COUGH. This disease, to which, on account of the violence of the cough that attends it, the Latin term "Pertussis" has been applied, and which from the recurrence of this cough in paroxysms has also obtained the popular designation "chin or kink-cough," appears to have been unknown to the ancients. No mention is made of it in the medical writings of the Greeks, Romans, or Arabians; but during several centuries it has prevailed in the various countries of Europe, and, from the frequency of its occurrence and the serious consequences of which it is sometimes productive, has much occupied the attention of physicians.

It commences with the symptoms of simple catarrh, and is indicated by cough and the expectoration of a clear limpid fluid, by redness of the conjunctivæ, a watery discharge from the eyes and nostrils, hoarseness, and occasional sneezing. These symptoms are attended by some degree of fever, which in general however is very slight; the patient is languid and out of spirits, but is free from pain, or complains only of soreness in the anterior part of the chest. During this stage the disease may be readily confounded with a common cold, but there is already some peculiarity in the cough, which occurs more in fits, and is more sonorous than in the latter malady. At the end of a period varying from one to two weeks the affection assumes a somewhat different character; the fits of coughing become longer and more frequent; each fit is commonly announced by a sensation of tickling in the larynx and trachea, during which the inspirations are irregular and incomplete, especially in children, whose countenances are at this time expressive of fear and anxiety. At the moment the fit comes on they cling with firmness to the persons or objects around them; if asleep at the time of its accession, they suddenly start up and place themselves in a sitting posture. The efforts of coughing are now repeated in such quick succession as to suspend almost completely the act of breathing: during their brief intervals we can with difficulty perceive any inspiratory movements, excepting at times when the cough is momentarily interrupted by a prolonged inspiration attended by a peculiar *whooping* noise, which has supplied a name for the affection, and which constitutes its characteristic symptom. In consequence of the obstruction to the circulation occasioned by these long continued efforts of coughing, the face and neck become swelled, and of a deep red or violet colour; the veins on these parts are distended almost to bursting; the eyes are prominent and bathed in tears; occasionally the patient becomes completely exhausted; the fit of coughing is interrupted for one or more minutes; it then recurs with the same violence, and the patient seems in imminent danger of suffocation, when the paroxysm is terminated by one or two long and *whooping* inspirations, and by the rejection of a limpid viscid fluid, which hangs in threads from the mouth, and to facilitate the discharge of which the patient inclines his body forwards. This fluid comes from the bronchi and pharynx, and sometimes also from the stomach; it is often mixed with portions of food which are rejected at the same time, and occasionally with particles of blood.

These paroxysms or fits of coughing continue for many minutes, and when they are very severe blood frequently issues from the nose, mouth, ears, or even from the eye-lids; they recur at various and often very short intervals, generally however more frequently and with greater severity by night than by day, and they are excited by the slightest causes, as by food or exercise, by any agitation or mental emotion. When the affection exists in a state of simplicity it is attended, even in this stage, with very little or no fever; the appetite continues as good as or better than in health, and the little patient, whose play was interrupted by the approach of the fit, immediately returns to it when the paroxysm is over; and during the intervals of these paroxysms often shows no other indications of disease than are furnished by the puffiness of the face and the redness and tumidity of the lips, which the interruption of the circulation during the violent and long continued efforts of coughing has occasioned.

In the intervals of the fits the chest sounds well on percussion, and on auscultation the respiratory murmur is heard pure, or mixed only with a little mucous râle on the posterior part of the chest, as in common catarrh. During the paroxysm breathing is almost completely suspended, and no respiratory murmur is audible except in the very short intervals which exist between the expulsive efforts of coughing; the prolonged and noisy inspiration which constitutes the pathognomonic character of hooping-cough seems to be limited to the larynx and trachea, and gives rise to no respiratory murmur audible on auscultation of the chest.

It is chiefly during this stage that hooping-cough becomes complicated with other diseases affecting the head or chest, on which its danger mainly depends. In children at the breast the most common complication is cerebral congestion, giving rise to convulsions; in persons more advanced in life the viscera of the chest become more frequently implicated, and it is to inflammation of the lungs and pleura that death, when it occurs, is generally attributable.

After the affection has presented the characters which we have described for a period which varies from two or three weeks to many months, the paroxysms become shorter and less frequent, and the cough ceases to be characteristic, but still continues to terminate in vomiting and in the discharge of sputa, which now resemble those of catarrh. The paroxysms become more and more rare, in some cases recur at regular intervals, and finally cease, but for some time afterwards they are easily renewed by any unusual exposure to cold.

The specific nature of the cough, and the insufficiency of the morbid changes noticed on dissection to account for the phenomena of hooping-cough, have led pathologists to seek for their interpretation in the condition of the pneumogastric nerves, but hitherto without success. M. Breschet indeed has in two cases remarked in these a redness externally, and a yellowness of their tissue, but no similar appearances have been observed by other physicians.

Hooping-cough prevails epidemically, and chiefly attacks children from birth to the period of second dentition, but it occasionally occurs in adult and even in old age. It rarely affects the same individual more than once, although this sometimes happens. It occurs in every variety of climate, and in all seasons, but is more general and more severe in cold than in tropical climates, and is most prevalent in seasons most favourable to catarrhal affections. It is of longer duration when it comes on in autumn or winter than when it makes its appearance in spring or summer; and like all other diseases that occur epidemically, it is much more severe in some years than in others.

Hooping-cough is one of those diseases that are communicable by contagion. It spreads very rapidly among children of the same family, and when it finds admission into a house very few of the young persons who have not previously had it escape; but they are protected from the disease if secluded from those previously infected. Hooping-cough is a very fatal disease, and the average annual mortality in London from 1849 to 1859 was 2190.

No method of treatment has hitherto been discovered by which the progress of hooping-cough can be arrested. We may mitigate its severity and somewhat diminish its duration, but it will run a certain course, and this course, in spite of all our efforts, will often be long. During the early stage of the disease the administration of emetics has appeared to be beneficial; in children they may be repeated every day, or every other day, for one or two weeks. Tartar emetic, on account of its solubility and the certainty of its operation, is the medicine best adapted to this purpose.

At a more advanced period of the disease great benefit is derived from the employment of narcotic and sedative medicines. Of these there is a great variety, each of which has had its advocates. We may particularly mention opium, hydrocyanic acid, belladonna, and Indian hemp; but on account of the powerful influence of these drugs on the system, the greatest caution should be observed in their administration to children. In some cases the administration of alum is particularly beneficial.

When the paroxysms are regularly intermittent, we may prescribe sulphate of quinine in the same doses, and almost with the same certainty of success, as in ague.

In protracted cases nothing is so efficacious in putting a stop to the cough as change of air, which often succeeds after all other means have been tried in vain.

At the commencement of the disease, and as long as any febrile symptoms continue, the diet should be of the mildest description; afterwards a more tonic and nourishing regimen may be allowed, not only with safety, but with advantage.

Cerebral congestions and inflammations of the lungs and pleuræ, when they occur during the course of hooping-cough, must be treated in the same manner as when existing under ordinary circumstances.

HOPFNER'S BLUE. [COLOURING MATTERS.]

HOPS (*Humulus lupulus* of Linnæus) are extensively cultivated for the flowers or seed-vessels, which give flavour and permanence to beer, by being boiled with the wort in brewing. They impart a pleasant bitter and aromatic flavour, and prevent the too rapid progress of fermentation. Beer which is well hopped will keep long and become very fine, without any of those artificial means of fining which make the common brewers' beer so much inferior in quality to that which is home-brewed.

Hops were introduced into England from Flanders about the year 1524. The most extensive plantations are in Kent, Sussex, and Herefordshire; but they are also cultivated in Worcestershire, Essex, Wiltshire, Hampshire, Gloucestershire, Surrey, and several other counties.

The hop is a slender climbing plant, which requires a very rich mellow soil and careful cultivation. It is very tender, and the produce is precarious, sometimes giving a great profit to the grower, and at other times failing altogether. The greatest quantity of hops is raised in Kent, but the finest quality in the neighbourhood of Farnham in Surrey. The soil of a hop-garden must be rich to a considerable depth, or made so artificially. The subsoil must be dry and sound; a porous rocky subsoil, covered with two or three feet of good vegetable mould, is the best for hops. The exposure should be towards the south, on the slope of a hill, or in a well-sheltered valley. Old rich pastures make the best hop-gardens. They should be dug two or more spits deep, and the sods buried at the bottom, where they will gradually decay and afford nourishment to the slender roots of the plants which strike deep. A very large quantity of the richest rotten dung, at least 100 cubic yards per acre, should be well incorporated with the soil by repeated ploughings, till it is entirely decomposed and produces that dark tint which is the sure sign of an abundance of humus. The ground should be prepared by laying it up with the spade in high ridges before winter, to expose it as much as possible to the mellowing influence of the frost. A succession of green crops, such as rye cut green or fed off with sheep, early turnips fed off in autumn, or spring tares, are an excellent preparation, by cleaning the land. It is better to be two or even three years in preparing the ground and getting it perfectly clean, than to plant the hops in a foul or unprepared soil.

The young plants are raised in beds, and may be raised from seed; but it is more usual to plant the young shoots which rise from the bottom of the stems of old plants. They are laid down in the earth till they strike, when they are cut off and planted in the nursery-bed. Care must be taken to have only one sort of hops in a plantation, that they may all ripen at the same time; but where there are very extensive hop-grounds it may be advantageous to have an earlier and a later sort in different divisions, so that they may be picked in succession. The varieties most esteemed are the Grape Hop, the White Vine, and the Golden Hop. The ground having been prepared for planting, it is divided by parallel lines, six or more feet apart, and short sticks are inserted in the ground along these lines at six feet distance from each other, so as to alternate in the rows, as is frequently done with cabbage-plants in gardens. At each stick a hole is dug two feet square and two feet deep, which is filled lightly with the earth dug out, together with a compost prepared with dung, lime, and earth, well mixed by repeated turning. Fresh dung should never be applied to hops. Three plants are placed in the middle of this hole six inches asunder, forming an equilateral triangle. A watering with liquid manure greatly assists their taking root, and they soon begin to show bines. A stick three or four feet long is then stuck in the middle of the three plants, and the bines are tied to these with twine or the shreds of Russia mats, till they lay hold and twine round them. During their growth the ground is well hoed and forked up around the roots, and some of the fine mould is thrown around the stems. In favourable seasons a few hops may be picked from these young plants in the autumn, but in general there is nothing the first year. Early in November the ground is carefully dug with the spade, and the earth being turned towards the plants, is left so all winter.

In the second year, early in spring, the billocks around the plants are opened, and the roots examined. The last year's shoots are cut off within an inch of the main stem, and all the suckers quite close to it.

The suckers form an agreeable vegetable for the table, dressed like asparagus. The earth is pressed round the roots, and the cut parts covered so as to exclude the air. A pole about twelve feet long is then firmly stuck in the ground near the plants; to this the bines are led and tied as they shoot, till they have taken hold of it. If by any accident the bine leaves the pole, it should be carefully brought back to it, and tied till it takes hold again. A stand ladder should be at hand to do this, when the bine has acquired some height. The ground being well hoed and the earth raised round the plants, the produce this year will average 4 cwts. per acre, if the season is favourable.

Some hop-planters plough up or dig the ground before winter; others prefer doing it in spring, in order not to hasten the shooting, which weakens the plants. The same operations of pruning the shoots, manuring, and placing poles, which were performed the preceding year, are carefully repeated. Particular attention is paid to proportion the length of the poles to the probable strength of the bines; for if the pole be too long, it draws up the bine, and makes it bear less: if it be too short, the bines entangle when they get beyond the poles, and cause confusion in the picking. In September, the flower containing the seed will be of a fine straw colour, turning to a brown; it is then in perfection. When it is over ripe, it acquires a darker tint. No time is now lost, and as many hands are procured as can be set a-picking; great numbers of men and women go out of the towns in the hopping season, and earn good wages in the hop plantations. During the picking they sleep in barns and outhouses. In the picking, the poles are taken down, and the stems cut 3 feet from the ground; if they were cut shorter it would weaken the root, by causing it to bleed. The poles are laid sloping over a frame of strong wood 9 feet long and 4 feet wide, supported by legs 3 feet high; this is called a bin. A piece of coarse cloth is fixed to this frame by hooks, so as to form a bag, which does not reach the ground. Three men or women, or four boys or girls, are placed on each side of the bin, and pick the hops from two poles at a time. Where they are very careful of the quality of the hops, as at Farnham, they divide them into three sorts: the green, which are not quite ripe; the light yellow-brown, which are in perfection; and the very dark, which are past their prime. Some go even further, and make several qualities according to colour and fragrance: for this purpose there are several baskets. The dew should be off entirely before they begin; for otherwise the hops might become musty, or take too long drying, and lose their fragrance. The hops when picked are dried on a hair cloth in a kiln. When they appear sufficiently dry at bottom they are turned; it is however thought by some hop-dryers that the turning of the hops is apt to injure them, and that it is best not to do so; but in order that the upper part may be dried equally with the lower, a wooden cover lined with tin plates is laid down over the hops on the hair-cloth, to within a few inches of the surface: this reverberates the heat, and the whole is dried equally. The heat must be carefully regulated, in order that it may not alter the colour. When the leaves of the hops become brittle and rub off easily, they are sufficiently dried. They are then laid in heaps on the floor, where they undergo a very slight heating. As soon as this is observed, they are *bagged*. This is done through a round hole 25 or 30 inches in diameter, made in the floor of the loft where the hops are laid. Under this hole is a bag, the mouth of which is drawn through the hole, and kept open by a hoop to which it is made fast. The hoop is somewhat larger than the hole, and the bag remains suspended; a handful of hops is now put into each corner of the bag, and there tied firmly by a cord. A bushel or two of hops are put into the bag, and a man gets into it to tread the hops tight. The bag does not reach the floor below. As the hops are packed by the feet, more are continually added till the bag is full. It is now taken off the hoop, and filled up with the hands as tight as possible. The corners are stuffed as soon as the mouth is partly sewn up, and tied as the lower corners were; when sewed close and tight, it is stored in a dry place till the hops are wanted for sale.

The crop of the third year will average 8 cwt. per acre. In some very extraordinary seasons, on good land, 15 cwt. have been picked per acre: in Flanders, where they manure with urine and the emptyings of privies, this is not an uncommon produce.

Rape cakes, malt dust, and woollen rags are used with good success in hop-grounds; bones have been tried, but with an uncertain result.

The hop is a diœcious plant, that is, some of the individuals are male plants, and others female, which have respectively flowers of a different construction and of different habitudes. Occasionally monœcious plants are met with, but these few are insufficient to fertilise all the female plants. The hops collected from bines in the neighbourhood of male plants are much larger, richer in aromatic and bitter principles, and a smaller proportion of such hops suffice to hop a given quantity of malt. The male or staminiferous flowers, which grow on stalks quite distinct from the female flowers, prepare the pollen, or fertilising dust, and afterwards wither away, when this dust has escaped from the anthers, and been committed to the air, to be by it conveyed to the female flowers. The female flowers are in the form of strobuli, or cones, consisting of scales, which have at their base the germ of the future seed, and which have the habit of enlarging, as the scales of the fir cones do, more particularly after the fertilisation of the ovule, or future seed, by a quantity of the pollen falling upon it. Though the pollen, from its extreme lightness, can be wafted to a considerable distance, and some seeds in each cone may be so fertilised, yet it would be well to rear a number of the male plants among the others, or along the hedges of the hop-gardens, to ensure the fertilisation of *all* the seeds. But as the farmers observe that the flowers of the male (termed, in Kent, seedling, blind, or wild hop; in Sussex, buck or cock hop) wither away, they generally extirpate them at the digging season, as unfruitful cumberers of the ground That this is an error may be proved in various ways, but an appeal to the result of an opposite practice is the most convincing. A bushel of hops, collected from plants of the fourth year, raised from seed, weighed 36 pounds, there being male plants near; a second instance, where the plants were raised from cuttings, weighed 35 pounds; while a bushel, grown in a garden where the male plants were always eradicated, weighed only 22 pounds. Besides the greater quantity of hops thus obtained, the aroma is much greater, and the strength of the bitter is much greater. After the period when the males have elaborated the pollen, and the strobuli of the females begun to enlarge, the males may be cut down, and the stalks employed to make cordage for hop-bags against the following harvest. In 1760 the Society of Arts awarded premiums for cloth made from the hop-bine. (Lance's 'Golden Farmer,' London, 1831.)

The poles are an expensive article; those of chestnut are the most durable, and also the dearest. They should be put into a shed during the winter: where this cannot be done, they are placed on end in the form of a cone, leaning against each other. If the top of these cones had a cap of thatch, it would greatly protect them from the weather: and it has been recommended to soak them in a solution of corrosive sublimate, according to Kyan's patent.

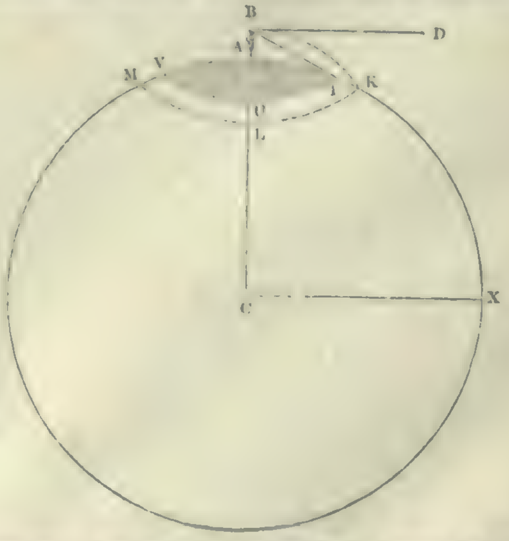
Besides the use of hops in brewing, they produce a bitter infusion and a tincture which are valuable in medicine for complaints in the stomach.

HORARY (Astronomy). The horary motion of the sun or a planet is the arc which it describes in one hour, or the angle which that arc subtends at the eye of the spectator.

HORDEIN. A substance extracted from barley, but which has been proved to be merely a mixture of starch and cellulose with a nitrogenous body.

HORDEUM DISTICHON (Linn.), *Medical Properties of.* The common summer barley is the kind directed in the Pharmacopœia to be used, but any of the finer sorts can be employed. Barley-water is either simple or compound: the former is merely a solution of the principles of the barley in boiling water; the latter has liquorice-root, figs, and raisins added. Both forms are demulcent and somewhat nutritious, and are useful in the treatment of mild cases of catarrh, or when acrid purgatives are taken, or when poisons have been swallowed. Barley is however an article of common consumption, either as an ingredient in soup or broth, particularly in Scotch broth, or as bread. It differs in some respect from wheat, in possessing less proteinaceous matter, and in having considerable bitterness in the husk. Farther, its starch is less soluble in water, and bread made of it is more difficult of digestion. It has, however, the advantage of being slightly laxative, and when it can be digested is a very proper article of diet for persons subject to habitual constipation. With a view to keep the bowels regular in infants, it sometimes forms as large as a fourth part of some of the prepared infants' food.

HORIZON (ὁρίζων, bounding). The physical horizon is the apparent circle by which the spectator's view is bounded when he is upon a level and uninterrupted plain, such as the surface of the sea. It differs from the astronomical horizon in two points: firstly, because the physical horizon *dips*, as it is called, or is not at the same level as the eye; and secondly, because the astronomical horizon always supposes the spec-



tator to be at the centre of the earth, and not at the surface. If A B represent a spectator standing upright, and C the centre of the earth, then, if the circle V A X revolve round the axis B C, the physical boundary is the circle described by T, or T U V, and the astronomical horizon is the plane traced out by C X (indefinitely extended) drawn parallel to B D, or perpendicular to C B; and the angle D B T is called the *dip* of the physical horizon. In consequence, however, of the refraction of light, by which the rays are curved, as in the dotted line drawn from B, the physical horizon is thrown farther than in the explanation just given; for instance, to the dotted circle K L M. The effect of this is to make the distance A T greater by about its twelfth part. The rough rule for finding the distance of the apparent horizon at sea is—$1\frac{1}{10}$ of the square root of the height of the spectator's eye, *in feet*, gives the distance of the physical horizon *in miles*. Thus, at a height of 100 feet, the horizon is 13 miles off.

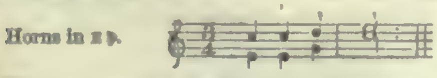
The astronomical horizon divides the heavens into a visible and invisible part. Properly speaking, it is the physical horizon which does this; but the distance of the fixed stars is so great, that the magnitude of the whole earth is but as a point, and the planes traced out by the revolutions of B D and C X may be confounded. It is not precisely the same thing with the planets, and least of all with the moon; but this belongs to PARALLAX. For the general use of the astronomical horizon, see SPHERE, DOCTRINE OF THE.

The plane of the horizon at any place is perpendicular to the direction of a plumb-line, or parallel to the surface of any fluid at rest. At sea, when it is necessary to take the altitude of any heavenly body, the physical horizon is, in tolerably fair weather, sufficiently well defined for the purpose, and, with proper allowance for its dip, is used accordingly. But in land observations with a sextant or other instrument requiring an horizon, the surface of a fluid (generally mercury) is used, which is called an *artificial horizon*, but might more properly be termed an artificial portion of a horizontal plane. A very slight knowledge of optics [REFLEXION] will show that the angle subtended at the eye by a star and its image in a fluid is double of the star's altitude: this angle, then, being measured and halved, the altitude of the star is found.

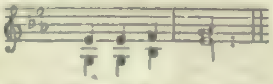
HORN, a musical wind instrument, which in its primitive state (that is, formed of the horn of an animal, or simply a shell) has been known from remote ages. Of the horns now in use, three are correctly denominated,—the *French horn*, the *bugle-horn*, and the *Russian horn*. These are made of brass. The *basset horn* (*corno bassetto*), and the *English horn* (*corno Inglese*), formed of wood, and partaking in no respect of what is generally considered the distinguishing character of the horn, seem to be improperly named.

The *French horn*, or now, *par excellence*, the *horn*, is a tube of about ten feet, very narrow at top, widening considerably at the bottom, and bent in rings for the convenience of the performer, as well as to render it more portable. It is not provided with holes, as the flute, &c., the production of the various sounds depending upon the lips of the player, the more or less pressure of his breath, and the insertion of the hand in the bell, or wide end, of the instrument. As a simple tube, the horn, governed by the laws of acoustics [ACOUSTICS], yields only the generating note, or tonic, and its aliquot parts, or harmonics, and, of course, would be confined to one key, but for the contrivances just mentioned, by which the length of the instrument is adjusted to the key required. This consists in *crooks* and *shanks*, or shifting pieces, added as wanted to the upper end of the tube; and thus the horn may be employed in all keys.

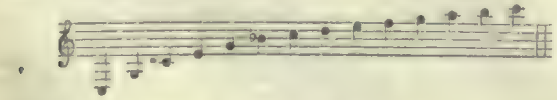
Music for the horn is always written in the key of C, an octave higher than played, and in the treble clef; and the key in which the instrument is to be tuned is indicated by the composer. Thus, if the piece be in E♭, the words "*corno in E♭*" are prefixed to the horn part. Example, as written:



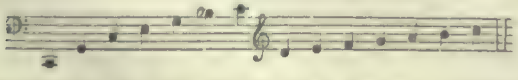
The notes actually played are—



The natural scale of the Horn is that of the trumpet, but an octave lower. It is written as follows:—

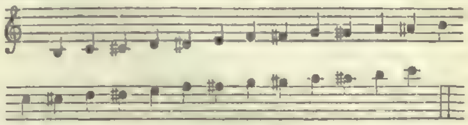


But the following are the sounds really produced:—

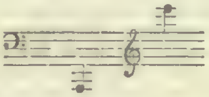


By introducing the hand into the *bell* of the horn, a tolerably good semitonic scale can be produced; and by the addition of two valves to the instrument, the performer can command a still more perfect scale of semitones.

The *bugle-horn* is a tube of three feet ten inches in length, doubled up in a small compass. The *keyed bugle*, or a bugle-horn with keys, is that now in common use, the scale of which is as follows:—



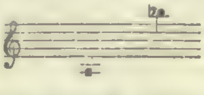
The *Russian horn* is an unbent brass tube, conical in shape, of various dimensions: the deepest toned is eight feet long and nine inches in diameter at the wide end, and the highest is two inches and a half in length, by one at the wide end. The former gives A, an octave below the first space in the bass; the latter gives E, the third additional line above the treble; or—



Some of these horns, though not all, have keys, producing one or two semitones; but generally every note has its separate horn, and a band of Russian horns counts almost as many individuals as diatonic notes in a scale of between four and five octaves.

Basset-horn, or *corno bassetto*. [BASSET-HORN.]

The *English horn*, or *corno Inglese*, is a deeper-toned oboe, but of rather larger dimensions, somewhat bent, the lower end very open, and is to the oboe what the basset-horn is to the clarionet, or what the viola is to the violin. The tone of this instrument is extremely pathetic, and by the Italians is thought so much to resemble the human voice, that they sometimes call it the *voce umana*. The scale of the *corno Inglese* (by which name it is most commonly known by musicians) is from A below the treble staff to B♭ above, or—



including all the semitones, except the lowest A♯.

Of late years M. Adolphe Sax, of Paris, has excited much attention for his *Sax-horns* and *Sax-trumpets*, which have had considerable influence on military music. It is stated in the Jury Report (class X A), that "his *Sax-horns* (double bass in E flat, and B flat) have left ophicleides very far in arrear; and his small treble Sax-horn in B flat is the only brass instrument known that can reach with certainty and just intonation the notes of the upper octave of the flute. His cornets-à-pistons are the best we are acquainted with. M. Sax has also created the class of *Saxophones*, brass instruments with a simple reed, similar to the clarionet. The effect of these new instruments possesses a charm equal to the originality of their tone, and they carry to the highest degree of perfection '*la voix expressive de l'orchestre*.'" Favourable mention is also made of his bass and double bass clarionets, in wood and metal. He has likewise filled up the gap in the tenor trombone, between the lower E and the lowest B flat; and his brass *bassoon* is very perfect. He has also contrived a means of continuing the sound in brass instruments from one note to another through all the enharmonic intervals; and he has invented a means of changing, by means of portable tubes, the monotonous character of the simple bugle, and giving it the power of producing all the intervals of the musical scale.

HORN MANUFACTURES. It is customary in England to use the same word to denote two quite different substances; namely, the branched bony horns of the stag genus; and the simple laminated horns of the ox genus and other kindred genera. The purposes to which the first of these kinds is applied are the same as those of bone and ivory, and the manufacture presents the same similarity. The other kind of horn, to which the French appropriate the name *corne* (while they apply the name *bois* to bony horns), is found in the ox, the antelope, and the goat and sheep. The structure of such horns may be described as a number of conical sheaths inserted one into another, the innermost lying upon the vascular membrane which covers the bony core. The tip, or that portion of the point of the horn which projects beyond the core, is very dense, and the several layers of which it is composed are scarcely distinguishable; while towards the base the layers may be readily distinguished, owing to their successive terminations forming prominent rings. Horn appears to consist of coagulated albumen; and there is a graduated connection between the substance of horns, nails, claws, hoofs, scales, hair, feathers, and even skin.

The principal kinds of horn employed in manufacturing operations are those of oxen, to which the hoofs of the same animals may be added. The horns of bulls and cows are preferred, those of bullocks being thin and of a coarse texture. The horns of goats and sheep are preferred, as being whiter and more transparent than those of any other animals. The first process in the manufacture of horn is to remove the bony core or pith, which is accomplished by steeping the horns in water for a month or more; by this operation the membrane which lies between the core and the horny sheath is so softened by putrefaction that the cores may be easily extracted. These are not thrown away, but are burnt to ashes, in which state they form the best material for the small tests or cupels employed by assayers of gold and silver. In some cases, instead of being thus used, the cores are boiled down in water, by which a quantity of fat is extracted, which, rising to the surface, is skimmed off and sold to the makers of yellow soap; while the liquid itself is used as a kind of glue, and is purchased by cloth-dressers for stiffening; and the remaining insoluble substance is crushed in a bone-mill for manure. The solid tip of the horn is sawn off with a frame-saw, and is employed for making knife-handles, umbrella-handles, the tops of whips, buttons, and various other articles. The remainder of the horn, employed for purposes for which thin laminæ are required, may either be left entire, or sawn into two or more lengths, according to the use to which it is to be applied. When divided the lower part, or that next the root of the horn, is frequently employed for making combs, while the portion which has formed the middle of the horn is used for lanterns and similar purposes. To prepare the horn for use, it is immersed in boiling water for about half an hour, by which it is softened; and, while hot from this operation, it is usually held in the flame of a coal or wood fire, until it acquires about the temperature of melting lead, and becomes so soft as to be semi-fluid. If the horn be from an old animal, care is taken to expose the inside as well as the outside to the action of the flame. Sometimes the softening is effected by pressure between two heated surfaces of iron. The slitting of the horn is performed while it is in the semi-fluid state, by a strong pointed knife resembling a pruning-knife; and, by the application of two pairs of pincers, one to each edge of the slit, the cylinder or cone of horn is opened until it is nearly flat. Several pieces are then exposed to pressure between alternate plates of iron, previously heated and greased, either in a press, or by placing them vertically in a strong iron trough, and compressing them by means of wedges. The degree of pressure applied depends on the proposed use of the horn; if it be intended to form very thin leaves for making lanterns, the pressure should be sufficiently strong to break the grain, or cause the laminæ of the horn to separate a little, so that the edge of a round-pointed knife may be inserted between them to complete the splitting or separation. The thin sheets of horn are then scraped with a blunt or wire-edged draw-knife, upon a board covered with bull's hide; and when thus smoothed and brought to the required thickness, they are polished by a woollen rag dipped in charcoal dust, a little water being added from time to time. They are afterwards rubbed with rotten-stone, and finally with horn shavings. The painted toys known under the name of Chinese sensitive leaves, which possess the curious property of curling up as if they were alive when laid upon a warm hand or near a fire, are made of the best of the thin films removed by the draw-knife. When the horn is to be converted into combs, the pressure applied in flattening must be as slight as possible: lest, by the breaking of the grain, the teeth of the comb become liable to split at the points. If a comb or any other article be required of greater size than can be made out of a single plate of horn, two or more may be united by the dexterous application of a degree of heat sufficient to melt but not to decompose the horn, assisted by pressure. When this is well managed, the junction cannot be perceived. The Chinese are skilful in this kind of work, as may be seen in the large globular lantern in the museum at the East India House, about four feet in diameter, composed entirely of small plates of coloured and painted horn.

Horns for combs are roughly cut by a hatchet or saw to the required shape, and then finished by rasps and scrapers. If required to be of a curved shape, they are first made flat, and after the teeth are cut they are softened in boiling water, and pressed until cold in a die of hard wood. Horn combs ornamented with openwork are extensively imported from France, where they are produced by pressure in steel dies. Horn shavings, when heated to a soft state, may easily be pressed into the form of combs, snuff-boxes, and other articles. The mode of cutting the teeth of combs is described under COMB MANUFACTURE.

Drinking-horns are now made by sawing the horn to the required length, scalding and roasting it over the fire, placing it while hot in a conical wooden mould, and driving a wooden plug firmly into the interior, to bring it into accurate shape. When cold and hard, it is fixed on a lathe, and turned and polished both inside and outside; and a groove or *chime* is cut with a gage-tool within the smaller end, for receiving the bottom. The horn is then softened before a fire, and the bottom, which is a round flat piece of horn cut out of a plate with a crown-saw, is dropped in at the larger end, and forced down until it reaches the chime. By the subsequent contraction of the horn in cooling, the bottom is so firmly fixed as to be perfectly water-tight.

In the manufacture of all articles made of fragments of horn compressed into a solid mass, great care is necessary to avoid the presence of grease, which would prevent perfect union. The masses of horn should be moved with wooden instruments while at the fire, and in carrying them to the moulds. Bell-pulls, the handles of table-knives and forks, knobs for drawers, and many other useful articles, are thus formed: care being taken, whenever the article is put into the mould in two or more pieces, to fit them together so that they may dovetail one into another.

Horn is easily dyed of various colours. In this country it is usually coloured of a rich reddish brown, and spotted to imitate tortoiseshell; this is effected by a mixture of pearl-ash, quicklime, and litharge or red lead, with water and a little pounded dragon's blood, applied hot to the parts of the horn which it is desired to colour. For a deeper colour the mixture may be applied twice; and for a blacker brown the dragon's blood may be omitted.

No part of the refuse of the horn manufacture is without its value. When exposed to a decomposing heat in close vessels, horn produces a large quantity of the gaseous compound which forms the base of prussic acid: on which account hoofs and horn cuttings are in great request among the manufacturers of Prussian blue, and of the beautiful yellow prussiate of potash. The clippings of the comb-maker are also used as manure. In the first year after they are spread over the soil, they have comparatively little effect; but during the next four or five their efficiency is considerable. The shavings of the lantern-maker, from their extremely thin and divided form, produce their full effect on the first crop.

Two recent improvements in the horn manufacture may be briefly noticed. One, introduced by M. Possoz, of Ixelles, in Belgium, consists in so heating, pressing, and rolling the horn, that the grain becomes straightened, the fibres lengthened and compressed, and the substance rendered so elastic and solid as to be fit for making into the ribs of umbrellas. Another, by Mr. Macpherson of Sheffield, relates to the manufacture of articles of furniture out of small waste fragments of horn and hoof. He cleanses the fragments from grease and dirt, soaks them in boiling water containing a little lime and potash, brings them into a cohesive mass by pressure between iron dies or moulds heated to 300° Fahr., and finally gives shape to them by pressure in moulds specially prepared. The finer the fragments, the better the result; if there be differences in quality, the best is kept at the surface. Varied effects may be produced by cementing different colours and kinds together; and inlays of mother-of-pearl or of metal may be used. Horn dust is better than any fragments; and one pound of horn will yield twenty-two cubic inches of such dust. The substance produced is well suited for table-tops, panels, work-boxes, dressing-cases, door knobs, &c. Hoof works up nearly as well as horn, and looks much like tortoiseshell. A table-top has been produced, of twelve square feet, and three-quarters of an inch thick, with forty pounds of horn. The solid tips of horns are worth 30*l.* a ton, but waste horn can be bought for a quarter of this price; and this relative cheapness appears to have suggested the mode of manufacture here described.

The manufacture of a kind of artificial horn has been established in France. It consists of gelatine, usually obtained from bones by treating them with muriatic acid, converted into a horny substance by tanning. Upon becoming hard and dry it resembles horn or tortoiseshell, both in appearance and in the facility with which it may be softened, by boiling in water with potash, and moulded to any required form. By inlaying with gold and silver, and staining with various colours, it may be rendered highly ornamental.

A considerable trade in horn has sprung up. The importations exceed 3000 tons per annum, the chief supply being from the East Indies. The importations in one year into Liverpool comprised 280 tons of deer horns, 200 of buffalo horns, 120 of buffalo tips, and 700 tons of ox and cow horns. Including the produce of home animals, the quantity of horns worked up is supposed to be not less than 6400 tons, worth 180,000*l.* The comb manufacturers alone consume 1300 tons, which produce 320,000*l.* worth of combs. Sheffield requires nearly 300,000 deer horns annually to make handles for cutlery.

HORN-WORKS AND CROWN-WORKS, are fortifications usually situated in advance of the principal works of a place. The rampart of the front, on the plan, is similar to that which is formed on each side of the polygon, supposed to surround a regular fortress; and on each flank a line of rampart returning from the nearest extremity of the front terminates on the ditch either of a bastion or ravelin on the enceinte of the place. The work is generally strengthened by a ravelin placed before the curtain between its two demi-bastions, and by a covered-way and glacis beyond the ditch; these return along the branch or wing on each side, and join the covered-way and glacis of the collateral bastion or ravelin of the enceinte.

The invention of horn-works is referred to the commencement of the 17th century. At first the plan of their rampart had simply the form of the letter M, the upper points being directed towards the country like horns; from which circumstance the work obtained its name. They appear also to have been at first formed of earth only, for the purpose of strengthening a place in daily expectation of a siege, when there were no outworks and when the bastions were small and very distant from each other. They were then constructed in front of the curtains, by the fire from whence the approach of the enemy towards their flanks might be opposed.

But the feeble defence which was made by such works when attacked in front, and the advantage of occupying beyond the principal fortress some position from whence, during the siege, the enemy might be annoyed in forming his approaches, or which, if gained by the latter, might enable him to command the town, almost immediately induced engineers to give to the horn-work the form first described, and to extend it considerably towards the country. Being however regarded but as a work of secondary importance in the defence of a place, the length of its front was seldom so great as that of the sides of the polygon on which the fortifications of the enceinte were constructed, and generally did not exceed 240 yards; which, since the relief of its rampart was necessarily nearly the same as that of the enceinte, scarcely allowed the ditch before its curtain to be effectively defended. The lengths of the branches or wings were regulated by the necessity of having the ditch and covered-way in front of the salient angles of the demi-bastions within the range of a fire of musketry from the collateral works towards which the ramparts of the wings were directed; and occasionally the latter were broken, on the plan, so as to form short flanks from whence a fire might be directed towards the nearest of those salient points.

That which has been found occasionally useful is too frequently, by an improper application, converted into a positive evil; this was the case with the works now being described; and at a very early period the multiplicity and injudicious disposition of them were subjects of animadversion among the best engineers. It often happened that they were constructed at great expense in situations where no end whatever was to be gained by them, and so close together that the defenders of their branches could not have avoided firing upon one another.

In proportion as the means employed in the attack of places were increased the earlier fortresses became incapable of affording room for the buildings necessary to lodge the troops, and contain in security the quantity of artillery and stores which the corresponding augmentation of the means of defence demanded; and hence it was sometimes found necessary to increase the extent of the advanced works about a place. This was done, at first, not by enlarging the dimensions of the half-bastions and curtain at the head of such works, but by making that head to consist of two or more fronts of fortification, in which case they took the name of double, triple, &c., horn-works, but more generally CROWN-WORKS. At a later time however the importance of advanced works was more highly appreciated; and, both by an improved disposition of them and by giving to their fronts dimensions equal to those of the general fronts of the place, they became not only free from the defects to which the old works were subject, but also capable of making a defence equal to that of a regular fortress.

The defects of the old horn-works consist in the expense of the construction being greater than is warranted by the benefit to be derived from them in the defence; in presenting to the enemy a front which, from its smallness, may be taken more easily than one of the fronts of the enceinte; in the revêtment of the latter being liable to be breached by a fire of artillery directed along the ditches of their wings from batteries formed on the glacis opposite the salient angles of the work; in the comparative security with which an enemy, after having made a lodgement in the work, might carry on his approaches in the interior in consequence of the protection afforded by the ramparts of the wings against any attempt of the besieged to impede him by sorties directed upon his flanks; and, lastly, in the large place d'armes the ditches afforded in which the assailants might assemble in large numbers unnoticed and in security for an assault. It should be observed, however, that Vauban, who constructed many such works, appears to have entertained a favourable opinion of them. He gives the preference to such as are formed immediately in front of a bastion; the wings being directed neither to that work nor to the collateral ravelins, but towards the curtains adjacent to the bastion. By this means the ditches of those wings are capable of being defended by the artillery of the curtains, while the revêtments of the latter are covered by the tenailles so as to render it impossible to breach them near the foot by a fire of artillery directed along those ditches. But his best application of a horn-work was made at Belfort, where he executed one entirely in advance of the glacis of the place; in consequence of this disposition the revêtment of the enceinte is effectually secured against being breached till after the horn-work is taken; while, at the gorge of the latter, the height of the terreplein above the ground at the foot of the glacis ensures the work itself from being taken by an assault in that direction.

A nearly similar disposition was adopted by Cormontaingne in executing the double crown-work at Metz. Beyond the glacis of that place, on one side, the ground rises with a gentle inclination, till, at some distance from thence, it forms one side of a deep valley; and along the brow are constructed, on nearly a straight line, three strong fronts of fortification. The ground is terminated on the left by an escarpment, which is crowned by a line of rampart with its covered-way and glacis; and on the right is a valley watered by a rivulet, which, being dammed, forms a lake capable of securing the works against an attack on that side. Each flank is further protected by a detached lunette, or redoubt: that on the right, being surrounded by water, is nearly inaccessible; and that on the left is strengthened by a system of counter-mines.

The ample capacity of the bastions and the direction of their faces, which are such as to prevent them from being enfiladed; the contraction of the ground before the works, by which the enemy would be reduced to the necessity of making his attack on a smaller extent of front than that of the defenders; and finally, the measures taken to secure the flanks, justly entitle this fortification to the character of being the most complete of its kind in Europe.

HORNPIPE, a rustic musical instrument, still, we believe, known in Wales, consisting of a wooden tube, with holes, and a reed. At each end is a horn; one to collect the wind blown into it by the performer, the other to augment the sound. The Hon. Daines Barrington states, ('Archæologia,' vol. iii., 1770) that "the tone, considering the materials of which the instrument is composed, is really very tolerable, and resembles an indifferent hautbois." In the Welsh language its name is *pib-corn*, which signifies, literally, *pipe-horn*. Sir John Hawkins quotes Chaucer to show that the hornpipe was a real, not an imaginary instrument; but in the 'Tatler,' No. 157, is a proof not only of its reality, but its actual existence so late as 1710.

Hornpipe is also the name of a dance; and Barrington is of opinion, that the dance-tunes called *Hornpipes* were originally composed for the instrument known by the same name. Hawkins says, that the hornpipe was invented in this country. It appears,—from the 'Dancing-Master,' 17th edit. 1721,—to have been in triple time, six crotchets in a bar; but the well-known tune, *The College Hornpipe*, is in duple measure.

HOROLO'GIUM (Constellation), the Clock, a southern constellation of Lacaille. It is cut by a line passing through Canopus to the southern part of Eridanus. Its principal stars (of which it is not worth while to make a table) are α and β, 34 of Piazzi and 229 of Lacaille, or 1315 and 956 of the 'B. A. Cat.,' both of the fifth magnitude.

HOROLOGY (from the Greek ὥρα, time or hour, and λόγος, a discourse), is an explanation of the principles of the measurement of time; but in its modern sense the term is usually applied as descriptive of that art which comprehends a knowledge of the action of the various machines used for the purpose of measuring time.

Sun-dials, which show apparent time, and clepsydræ, which give a rude approximation to mean time, were the earliest machines used in the measurement of time. [CLEPSYDRA; SUNDIAL.] We shall in this article only treat of those pieces of mechanism, used for the measurement of time, which are kept in motion either by the constant action of gravity through the medium of a weight, or by the elastic force of a spring, and which have received names varying according to the duties they have to perform. Thus, the term *timepiece* is applied to any piece which is intended merely to mark the time without striking the hour; a *clock* is one which, in addition to showing the time, strikes every hour, on a bell or spring, a number of strokes corresponding to the hour of the day or night indicated by the hands at the time; a *quarter clock* is one which also strikes the quarters as the hand successively arrives at them; a *watch* is a pocket timepiece; and a *repeater* is a watch which by means of any mechanical contrivance can at pleasure be made to repeat the hour, or hour and quarters.

History of Clocks and Watches.—The early history of clocks and watches is enveloped in so much obscurity, that it would be almost impossible to point out any individual who could with propriety be called the inventor. The term *horologium* was used very early in different parts of Europe; but this word being formerly applied indiscriminately to a sun-dial, as well as a clock, nothing decisive can be inferred from its use. Striking clocks were known in Italy as early as the latter part of the 13th or beginning of the 14th century. A fine imposed on the chief-justice of the King's Bench in 1288, was applied to the purpose of furnishing a clock for the famous clock-house near Westminster Hall. In the reign of Henry VI., the king gave the keeping of this clock to William Warby, dean of St. Stephen's, together with 6*d.* per day to be received at the exchequer. St. Mary's at Oxford was furnished with a clock in 1523, out of fines imposed on the students of the university. The middle of the 14th century seems to be the time which affords the first certain evidence of the existence of what would be now called a clock, or regulated horological machine. The first clock at Bologna was fixed up in 1356. Henry de Wyck, a German artist, placed a clock in the tower of the palace of Charles V. about the year 1364. Mention is made in Rymer's 'Fœdera,' of protection being given by Edward III. to three Dutch horologers who were invited from Delft into England in the year 1368. Conradus Dasypodius gives an account of a clock erected at Strasburg about 1370. According to Froissart, Courtray had a clock about the same period, which was taken away by the Duke of Burgundy in 1382. Lehmann informs us that there was a clock at Spire in 1395. Nürnberg had a clock in the year 1462; Auxerre had one in 1483, and Venice in 1497. It appears, from a letter written by Ambrosius Camaldulensis (lib. xv. epis. 4) to Nicolaus of Florence, that clocks were not very uncommon in private families on the Continent about the end of the 15th century; and there is good reason for supposing that they began to become general in England about the same period. The conclusion to be drawn from the evidence here adduced is, that a regulated horological machine is neither of so ancient a date as some writers suppose, nor yet the more recent invention of the last two centuries; and that the inventor is not certainly known. Ferdinand Berthoud was of opinion that a clock, such as that of Henry de Wyck, is not the invention of one man, but a compound of successive inventions, each worthy of a separate contriver. This supposition is confirmed by analogy; for the clocks and watches of the present day have been brought to their present degree of perfection by a series of successive inventions and improvements upon what may now be called the rude clock of De Wyck, the most ancient clock of which we have a description. De Wyck's clock was regulated by a balance in the following manner (*fig.* 1):—The teeth of the crown-wheel E act on two small levers F G, called pallets, which project from and form part of an upright staff or spindle C D, on which is fixed the balance A B; and the mode of adjusting the clock to time was by shifting the two weights W W nearer to or farther from the centre.

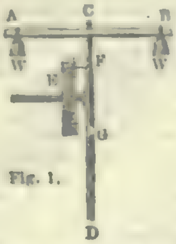


Fig. 1.

Although this clock of De Wyck's, and indeed all those made with a balance for the regulator, without any regulation spring, must have been very imperfect machines, we find that so early as 1484 Walther, and after him the landgrave of Hesse, made use of a balance-clock for astronomical observations. Such, indeed, seems to have been the comparative utility of the clock thus early for astronomical purposes, that Gemma Frisius proposed the use of a portable one for ascertaining the longitude at sea about the year 1530. In 1560 Tycho Brahé possessed four clocks, which indicated hours, minutes, and seconds; the largest had but three wheels, the diameter of one of them being 3 feet, and containing 1200 teeth, a proof of the imperfect state of clock-work at that period. Tycho also observed irregularities in his clocks dependent upon changes in the atmosphere, but does not appear to have been aware how they were produced. In 1577 Moestlin had a clock which made 2528 beats in an hour, and by counting the number of beats made during the time of the sun's passage over a meridian, the sun's diameter was determined to be 34′ 13″. At what time the size of clocks was reduced to a state of portability is uncertain, but it must have been prior to 1544; for in that year the corporation of master clock-makers at Paris obtained from Francis I. a statute in their favour, forbidding any one who was not an admitted master to make clocks, watches, or alarms, *large* or *small*. Before portable clocks could be made, the substitution of the main-spring for a weight, as the moving power, must have taken place; and this may be considered a second era in horology, from which may be dated the application of the fusee; for these inventions completely altered the form and principles of horological machines.

Such was the state of clock-work when Galileo observed that heavy bodies, suspended by strings of the same length, made their vibrations, whether in long or short arcs, in very nearly, if not exactly, the same spaces of time. Although he never applied the pendulum as a regulator to supersede the balance in clocks, yet his discovery was the prelude to a third era in clock-work, namely, the origin of the pendulum clock. The honour of first applying the pendulum to a clock has been a matter of much contention. Huyghens, whether the inventor or not, undoubtedly applied it in the more masterly and scientific manner, and hence has generally been considered the inventor; but it is now known that a London artist, named Richard Harris, invented and made a long-pendulum clock in 1641. Very soon after the application of the pendulum to clocks, the idea of Gemma Frisius was attempted to be realised by the ingenious Huyghens in the construction of a marine clock. He also discovered that its pendulum vibrated slower as it approached the equator, which has led the way to a subsequent discovery that the earth is not a globe, but an oblate spheroid. In 1676, Barlow, a London clockmaker, invented the repeating mechanism by which the hour last struck may be known by pulling a string. Several artists followed in the same line, particularly Quare, Julien le Roy, Collier, Largay, and Thiout. Clocks were soon after this made to show not only mean but apparent time. The principal artists employed in this more curious than useful part of horology were Sully, Father Alexander, Le Bon, Le Roy, Kriegseissen, Enderlin, L'Admiraud, Passement, Rivar, and Graham. The anchor escapement was the work of Clement, a London clockmaker, in 1680. This change in the escapement introduced the practice of suspending the pendulum by a thin and flexible spring. The seconds' pendulum, with this escapement, was called the *royal* pendulum.

Another era in the history of clock-work commenced with the beginning of the 18th century. In 1715 George Graham sought for a means of rectifying the errors of the pendulum, caused by the contraction and expansion of metals under changes of temperature; and this means he found in the celebrated *mercurial pendulum*. John Harrison improved on Graham's arrangement of the pendulum; and Graham himself afterwards introduced his *dead-beat escapement*, as an improvement on the anchor or recoil escapement previously in use. From the days of Graham and Harrison successive improvements have been introduced in every part of the art. Such of those as are of primary importance will be noticed as we proceed.

Chronometers.—A chronometer, an eight-day spring clock, a time-piece, and a pocket watch have this in common,—that their source of power is derived from a coiled spring, and not from a pendulum. Chronometers are in extensive use for determining the longitude at sea, and for other purposes where an accurate measure of time is required, combined with great portability in the instrument. The general appearance of what is termed a pocket chronometer is that of a common watch; and it is generally made to go the same time with once winding up—namely, thirty hours. Those used for nautical purposes are larger, having dial-plates from three to four inches in diameter, and are usually made to go from two to eight days between the times of winding up; they have, in addition to the hour, minute, and second circles, one on which a hand denotes the time in days that the piece has been going since the last winding up. Each chronometer is well secured in a brass box, mounted on gimbals, in order that the machine may preserve one uniform position, and is inclosed in a mahogany case.

A chronometer has for its moving power a main-spring, the variable force of which is equalised or rendered uniform by the introduction of the *fusee*, a very beautiful contrivance. This fusee is a variable lever, upon which the main-spring acts through the medium of the chain. It is a mathematical curve which has this peculiar property, that as the chain winds upon it, the distance from the centre of motion of the fusee to the semidiameter of the chain which is in contact with it continually varies. The variation is in this proportion,—namely, that the distance from the centre of motion of the fusee to the semidiameter of the chain at that point where it leaves the fusee for the barrel, multiplied by the force of the main-spring acting on the chain at that time, shall be a constant quantity; that is, shall be the same whatever point of the fusee may be taken. Thus, at any given distance from the centre of motion of the fusee, its power to turn any machinery is uniformly the same; and as the great or main wheel, which communicates motion to all the rest, is attached to the fusee, their centres of motion coinciding with each other, it follows that the power at the teeth of the main wheel is perfectly uniform: this power is transmitted through the medium of a train of wheels and pinions till it comes to the escapement.

A chronometer differs from a common watch in the escapement, and in having a compensation for heat and cold. The peculiar mode of effecting this compensation consists in having what is technically termed an *expansion balance*. The *figs.* 2 and 3 represent each a balance,—some being made with weights, W W, as in *fig.* 2; others with screws, as in *fig.* 3. Each consists mainly of two segments, and each segment is of steel on the concave side and of brass on the convex; a steel bar, A B, unites them. When such an apparatus is in use, any increase of temperature diminishes the elastic force of the balance-spring, which would cause the machine to lose; but the same degree of heat expands the outer rim of the balance, which is brass, more than it does the inner one, which is steel. Not being able to separate, a curvature of the whole arm takes place, which carries the weight W towards the centre, whereby the inertia of the balance is so much lessened as to allow the balance-spring to exert the same influence as it had previous to the change of temperature. Again, a diminution of temperature increases the elasticity of the spring, which would cause the machine to gain; but the brass contracting more than the steel, produces a curvature of the arm outwards, which increases the inertia of the balance, and allows the spring no more influence over it than it had previous to the change of temperature. The proper situations of the weights W W are found by experiments on the rate of the machine. It is evident that the nearer the weights are to the moveable ends *a a* of the arms, the greater will be the space through which they move by any change of temperature, and consequently the greater the variation in the inertia of the balance; whence, if an increase of temperature causes the machine to lose, or a decrease of temperature causes it to gain, it shows the compensation not to be sufficiently active. In adjusting those balances made with screws, it will readily be perceived that the moving in or out the screws 4 4 will produce a greater effect than 3 3, and these again greater than 2 2, and so on; and, also, that in the adjustment two opposite screws must always be moved in or out the same quantity. The mean-time screws C C can produce no effect on the compensation, as no motion is given to them by the curvature of the arms. It has been found by experiment, that in every balance-spring of sufficient length, there is a part of it which will be isochronal, or nearly so; and this length

Fig. 2.

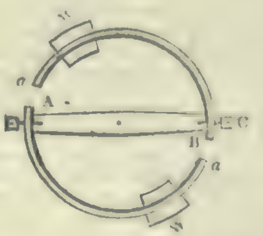
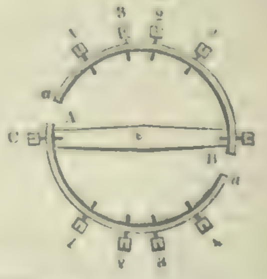


Fig. 3.



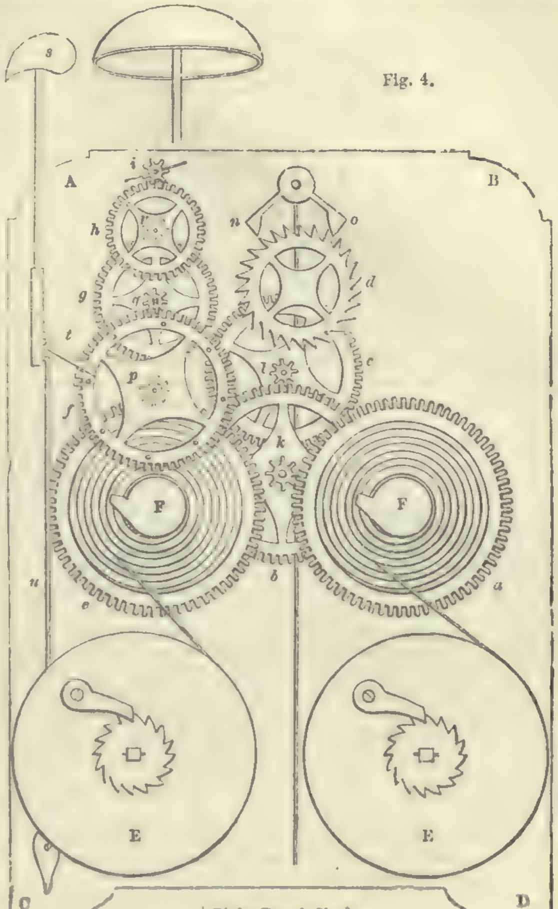
being found, it is not desirable to alter it in bringing the machine to time. To effect an adjustment, the two screws C C have been introduced, the drawing out of which from the centre causes the machine to lose, and the screwing them in to gain.

Many important matters relating to chronometers apply in a smaller degree to spring clocks and to pocket-watches, and will receive notice as we go on. But it is necessary here to say a few words concerning the *competitive trials* of chronometers, which have partly resulted from, and have partly suggested the beautiful inventions perfected within the last few years by Eiffe, Frodsham, Loseby, Dent, and others. Between the years 1822 and 1835, the Admiralty gave rewards as prizes for the good performance of individual chronometers: two or three sums being given annually to the makers of those which showed the smallest amount of error. Nothing was given for any new *principle;* but the general construction was improved by this competition. The relative order of merit was arrived at by taking the number of seconds in the greatest difference between one week's indications and the next, and adding to it twice the greatest difference between one week's rate and the next; the sum was the *trial number;* and that chronometer gained the prize which exhibited the *smallest* trial number. The trials were conducted at Greenwich Observatory, under the Astronomer Royal. After the year 1835 the prizes were withdrawn; but the makers were equally ready to compete, on the score of reputation and commercial advantage. The test was rendered more severe; for every chronometer was exposed in the open air to the fiercest cold of winter; and at other times to the air of a chamber heated to 100° Fahr. In successive years different makers obtained the post of honour; for instance Poole in 1845, Hutton in 1846, Frodsham in 1847, Hewett in 1848, Eiffe in 1849. In the five years here indicated, 219 chronometers were tested at Greenwich; of which 79 were bought for public use, at a maximum price of 62*l*. During the course of these refined experiments, a fact was observed which amounts almost to a new discovery. However perfect may be the compensation of a chronometer for certain temperatures, it was found that it did not remain constant for *all* temperatures. If a chronometer be planned to resist great cold and great heat, it *gains* at medium temperatures; but if specially adapted for the latter, it errs slightly in very cold and very hot weather. The late Mr. Dent explained this fact by supposing that the inertia of a spring balance, as usually constructed, cannot be made to vary uniformly according to temperature, but will vary more rapidly in cold weather than in hot. Chronometer-makers at once set about devising a remedy; and this remedy, however produced, is called the *secondary compensation.* Loseby, Dent, Eiffe, Molyneux, and other makers, have invented highly-curious arrangements of spring balance, all of which have been severely tested at Greenwich, and some of them rewarded by government grants. Loseby's arrangement, which received high commendation from the Astronomer Royal, may be thus briefly described. Attached to the balance is a curved tube containing mercury. The mercury, on expanding with an increase of temperature, arrives at certain parts of the tube inclined in different degrees to the radii of the balance; and therefore its successive expansions produce successive effects of different magnitudes on the momentum of the balance. By giving different forms to the tube, the law of the successive alteration of the momentum may be made to adapt itself to the law of alteration of the elasticity of the spring, whatever that law may be.

Spring Clocks.—In describing spring-clocks, we shall at the same time treat of many parts of the mechanism which are applicable likewise to chronometers, but not described in the foregoing paragraphs.

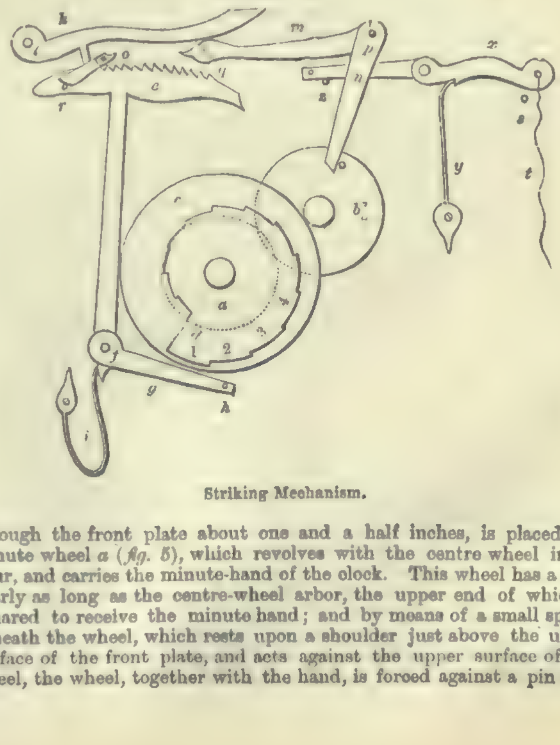
In *fig.* 4, A B C D may be taken as representing the front plate of an eight-day spring clock (which is supposed to be transparent), and is attached to another plate of similar form by five strong pillars between which the wheels here shown are placed. E E are two barrels containing springs; the one on the right gives motion to the train of wheels called the *going* or *watch* train; the other to the *striking* train of wheels *e*, *f*, *g*, *h*, and fly *i*. In producing the series of movements, *a* is the main wheel of 96 teeth, acting in the centre wheel-pinion *k* of eight leaves, to which is attached the centre wheel *b;* this revolves in an hour, and acts in the third wheel-pinion *l*, on which is fixed the third wheel *c*, acting in the swing or scape wheel-pinion *m* (not seen in the cut); to this pinion is fixed the swing-wheel *d*, whose teeth act alternately on the two pallets *n o*, and thereby give motion to the pendulum by means of a piece attached to the arbor of the pallets, one end of which enters a slit made in the pendulum for its reception. F F are the two fusees, the use of which has already been described in connection with chronometers. The method in which the fusees are attached to their respective wheels *a* and *e* is shown in *fig.* 6, where is the main wheel of 96 teeth hollowed out to receive the click *b* and its spring *c* which are attached to the wheel, the ratchet *d* being attached to the under side of the fusee by two screws. In *fig.* 4, *e* is the striking main wheel, having 84 teeth; this drives the pinion *p* of eight leaves, on which is the pin-wheel *f* of 64 teeth, into the rim of which are put eight pins to lift the hammer *s*, by acting upon its tail *t*. The pin-wheel *f* drives the pallet pinion *q* of eight leaves, on which is fixed the pallet-wheel *g* of 56 teeth; this pallet wheel acts in the warning wheel-pinion *r* of seven leaves, on which is the warning-wheel *h* of 48 or 50 teeth, acting in the fly pinion *i*. When in action a pin in the pin-wheel catches the tail of the hammer *t*, and raising it, the hammer-head *s* recedes from the bell; and as soon as the pin leaves the tail of the hammer, the force of the spring *u* acting on the lower part of the hammer produces a blow on the bell. The number of strokes on the bell is regulated by mechanism placed on the outside of the front plate of the clock, but is removed from the figure just described, to prevent confusion. (See *fig.* 5.) On the centre wheel-pinion *k* (*fig.* 4), whose arbor comes through the front plate about one and a half inches, is placed the minute wheel *a* (*fig.* 5), which revolves with the centre wheel in an hour, and carries the minute-hand of the clock. This wheel has a pipe nearly as long as the centre-wheel arbor, the upper end of which is squared to receive the minute hand; and by means of a small spring beneath the wheel, which rests upon a shoulder just above the upper surface of the front plate, and acts against the upper surface of the wheel, the wheel, together with the hand, is forced against a pin over

Fig. 4.



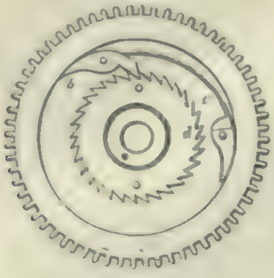
Eight-Days' Clock.

Fig. 5.



Striking Mechanism.

Fig. 6.

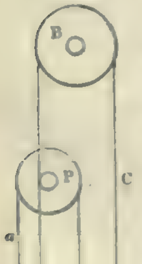


Fusee-wheel.

the hand. The whole of the wheels in this group can therefore be turned forwards or backwards without disturbing the internal mechanism of the clock, or rather that part of it which is called the *going* or *watch* train; for the minute-wheel *a* gives motion to another minute-wheel *b*, which, as it must revolve also in an hour, has the same number of teeth as *a*. A pinion in the centre of the wheel *b* has six leaves, and acts in the hour-wheel *c* of 72 teeth, which is placed over the minute-wheel *a*, and consequently revolves once in 12 hours, and has screwed to its socket, at the upper end, the hour-hand. To the socket of the hour-wheel, about one-eighth of an inch above the wheel, is fixed a piece in which are 12 steps, each of which includes an angle of 30°, or a twelfth part of a circle; this piece is called the *snail*, and is represented by *d*. *e* is a rack whose centre of motion is a stud or pin *f*, on which it acts by means of a pipe about half an inch long, and on to the upper end of which is riveted the rack-tail *g*; in this rack-tail is a short pin *h*, pointing perpendicularly downwards to the front plate of the clock. The rack lies about the tenth of an inch above the front plate; but the pipe which acts on the stud is long enough to carry the rack-tail just clear of the snail when the rack is forced back by the spring *i*; whilst the pin *h* is long enough to strike against the steps in the snail, and yet so short as to be perfectly free of the hour-wheel *c*. Near this is *k*, the rack-hook moving freely on a stud; *m* the lifting piece, also moving freely on a stud *p*; *n* the tail of the lifting-piece firmly pinned on to the upper part, and moving with it; *o* the gathering pallet, which has a square hole through it, and is fixed upon the square end of the arbor *q* of the wheel *g* (*fig.* 4) which revolves once for every blow given by the hammer. A pin in the warning-wheel *h* always stands in the same position when the striking part is at rest, which is the position represented in *fig.* 4. On the end of the lifting-piece is a small piece *q* (*fig.* 5), which passes through a slit in the front plate, and resting on the bottom of the slit, keeps the lifting piece in its proper position. The gathering pallet *o* rests on a pin *r* in the rack, and thereby prevents any motion in the internal wheel-work of the striking train. Such being the mechanism, the mode of action will be understood from a study of the figures, without a detailed description. A small piece *x* is called the *pull-piece*, by pulling a string at the end of which the lifting-piece is raised, and the clock is made to repeat the hour last struck at any required time. *y* is a spring to force the pull-piece *x* against the pin *z* fixed in the plate of the clock; *s* is another pin to limit the motion given to the pull-piece *x* when the string *t* is pulled.

Pocket-watches.—Without attempting to notice the numerous improvements in spring clocks, we shall proceed briefly to describe those features in a pocket watch which are of a distinctive character.

Fig. 7.



Endless Cord.

When clocks and watches had acquired a certain degree of accuracy in their performance, the time lost in winding up (especially when it had to be done every twenty-four hours) became a matter of importance; and there have been several inventions to remedy this evil, by producing what is called a *maintaining power*. By Huyghens the clock was kept going while winding by means of an *endless cord*, as in *fig.* 7. B is the clock-barrel; C, that portion of the line which comes from the barrel to the weight; P, a pulley for the line to run over; Q, a pulley for the line to run under, and to which is attached a small weight *w*. It will be seen by inspection that the hand applied to that part of the line marked *a* will be able to raise the weight W without depriving the barrel B of any portion of the power by which it is urged forward, and which power in this arrangement is equal to one-half of the weight W. Another kind of maintaining power is the *forcing spring*, shown in *fig.* 8. A lever A, whose centre of motion is *o*, has a notch cut in its end, into which is jointed a small lever *c*, whose centre of motion is *x*; this small lever is kept in its proper position against the bottom of the notch, as shown in A, and also in B (which is only another position of the lever), by a slight spring *s*. D is a strong spring which acts constantly on the lever A, having a tendency to force it into the position represented by B, in which it is not in action. Previous to winding the clock up, the end E of the lever is depressed and brought from position B to that of A; and in its progress in passing a tooth of the wheel the small lever *c* assumes the position represented in *fig.* 9, which it is allowed to do by the very slender spring *s*. As soon as the tooth is passed, the pressure of *s* obliges the lever *c* to return to its original place; and by the pressure of its opposite end on the bottom of the notch in which it is inserted, the lever A is prevented from regaining its former position by the pressure of the piece *c* on the tooth of the wheel—until the wheel shall have advanced so far as to have allowed its escape, when the lever regains its position B, where it remains till another winding becomes necessary. It will be evident that so long as *c* remains on a tooth, the wheel will be urged forward by the action of the spring D. *e e* are two pins which are fixed in the plate of the clock, and serve to determine the quantity of motion given to the lever A.

Fig. 8.

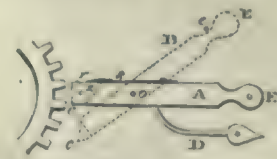
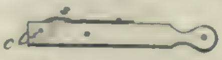


Fig. 9.



Forcing-spring.

1 2

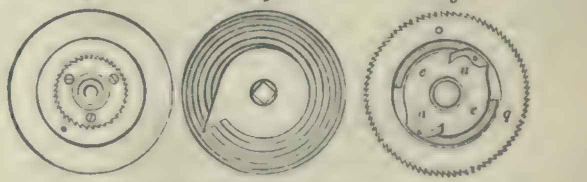


Fig. 10.

3 4 5

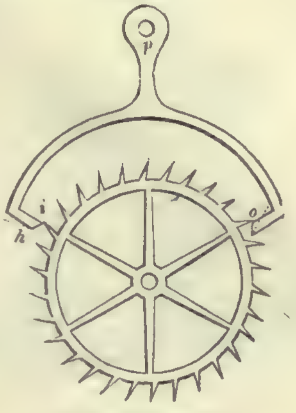
Harrison's Maintaining Power—Going Fusee.

1, Fusee auxiliary ratchet, and fusee-wheel attached; 2, fusee-wheel and auxiliary spring, separate; 3, 4, upper and under sides of the fusee, separate; 5, auxiliary ratchet *q*, with clicks *a a*, and springs *e e*, attached.

Harrison's contrivance for the same purpose, however, is the one now in general use, both in clocks and watches, and is admirably adapted to the purpose. When this principle is applied to a fusee, it is termed a *going fusee*; but *maintaining power*, as a more comprehensive term, is now generally applied. Into the hollow of the fusee-wheel is placed a circular spring *a b c*, (*Fig.* 10), which is secured to the wheel by a pin at about one fourth of its circumference from the end *a*, namely, at *b*. The wheel has a short notch cut through it, near the other end of the spring. The spring passes over this notch; and by means of a pin *c*, fixed firmly in the spring and projecting through the notch in the wheel, a motion is allowed to the spring, which in extent is equal to the difference between the length of the notch in the wheel and the thickness of the pin which passes through it. It is the reaction of this spring through the short distance already mentioned which maintains the motion in the watch during the time of winding up. Instead of any click and spring being attached to this fusee-wheel, as in an ordinary eight days' clock, there is a circular disc of steel, rather larger than the bottom of the fusee, and smaller than the fusee-wheel, having very fine ratchet-teeth cut in its edge, and two clicks *a a* and springs *e e* on its upper surface, in which the ratchet fixed on the under side of the fusee, and called the fusee-ratchet, acts. The steel-ratchet is called the auxiliary-ratchet, and its teeth stand in a direction opposed to those of the fusee ratchet. We will now suppose the auxiliary ratchet to be laid on to the fusee-wheel over the spring *a b c*; a hole in its centre passing over a short pipe in the centre of the fusee-wheel retaining it in its situation; the pin *c*, which we have described as projecting through the notch in the fusee-wheel, also projecting upwards just equal to the thickness of the auxiliary-ratchet, through which it likewise passes; and the pin exactly fitting the hole in the ratchet. In this situation the wheel and ratchet are ready to receive the fusee with its ratchet; but it must be borne in mind, that though the pin *c* fits exactly in the hole in the auxiliary-ratchet, and thereby prevents it from turning round, it does not prevent its having as much motion as the spring itself has in the notch in the fusee-wheel; the spring must also be conceived to have been forced into its place with the pin pressing strongly against the end of the notch *o*. The fusee is now attached to the wheel by passing its arbor through the hole in the centre of the wheel, and is secured in its place by a pin and collet on the opposite side, which prevent their separation, at the same time allowing the fusee to turn with a moderate degree of force. In this state the fusee, &c., must be considered as placed within the frames of the clock or watch in connection with the other part of the train of wheels, &c. A click, or, as it is sometimes called, a detent, is also placed between the frames, and by means of a slight spring is made to act in the teeth of the auxiliary-ratchet. The action of the whole apparatus will be understood by comparing the relative positions of the several parts. The space through which the spring *a b c* acts in the notch *o p* with sufficient force to maintain the motion of the watch, is about equal to two teeth of the fusee-wheel; and the time in which the fusee-wheel goes through a distance equal to two teeth varies in different watches from 10 to 12 minutes, a time more than sufficient for the operation of winding.

We must next describe the *escapement*, so important in horology. This term is applied to a combination of parts in a clock or watch, which has for its object the conversion of the circular motion of the wheels into a vibratory motion, as exhibited in the pendulum. In the description we are about to give, the term will be made to include the scape-wheel, the pallets with their arbor or axis, and a bent lever attached thereto, called the crutch, which last piece maintains the motion of the pendulum. In a watch this combination consists of the scape-wheel, together with all those parts lying between it and the balance, and which are concerned in converting the circular motion of the wheels into the alternating one of the balance. In Graham's *dead-beat escapement* the distance between the centre of motion *p* of the pallets and the centre of the scape-wheel is equal to one diameter of the scape-wheel. In *fig.* 11, the tooth *i* has just given impulse to the pallet P and escaped from it; the tooth *o* has in consequence fallen upon that part of the pallet Q called its arc of rest, which, in both pallets, is formed by a circle struck from the centre of motion *p* of the pallets. The impulse given by *i* causes the pendulum, and with it the pallets, to vibrate some distance after *i* has left P and *o* has fallen on Q; but the arc of rest being concentric with the centre of motion of the pallets, the wheel ceases to rotate, or remains *dead*, until the pendulum by its returning vibration lifts the pallet Q so high as to allow the tooth *o* to get upon the face or inclined plane of the pallet, upon which it then acts. The tooth drives up the pallet, and with it the pendulum, until the tooth *o* escapes from the pallet Q; when another tooth *h*, on the opposite side of the wheel, falls on the arc of rest of the pallet P, which arc is in this pallet on the outside, and on which the tooth rests until by the return of the pendulum the pallet P is lifted so high as to allow *h* to get on the inclined plane or face of the pallet P, upon which it acts. The tooth raises the pallet and with it the pendulum, till it escapes and gains the position *i*, when the same process is repeated: the wheel alternately giving impulse to one pallet and resting on the circular part of the other, which we have denominated the arc of rest. When the pendulum is in a state of rest, some one tooth is always resting on one of the circular arcs; the pendulum being put in motion brings a pallet into a position to receive an impulse from the wheel-tooth, when the process already described commences.

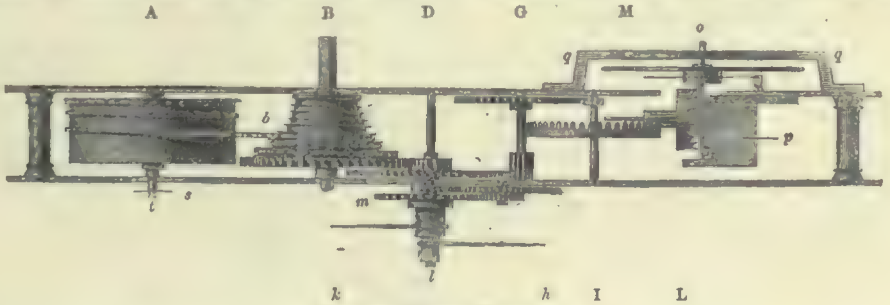
Fig. 11.



Dead-Beat Escapement.

Most of the great improvements in pocket watches have been made in the *horizontal* or *flat* forms; but the common *vertical* watch must be first described.

Fig. 12.



Section of Vertical Watch.

The annexed cut (*fig.* 12) represents such a watch as it would appear if the dial (which is here omitted) were turned downwards. A is the barrel; B, the fusee; *b*, the chain by which motion is communicated from the barrel to the fusee, on which is the great or fusee wheel acting on the centre-wheel pinion D, on which is riveted the centre-wheel: the arbor of the pinion D being prolonged through the plate of the watch as far as *l*. The centre-wheel and its pinion revolve in an hour. Upon that part of the arbor D which is on the outside of the plate or frame is placed the cannon-pinion, which has a hole quite through it for the reception of the centre-wheel arbor, on which it turns spring-tight. The cannon-pinion is secured in its place by a small pin through the end of the centre-wheel arbor *l*, the end of the pinion being squared to receive the minute-hand *h*. The cannon-pinion has 12 leaves acting in the minute-wheel, of 48 teeth, causing the latter to revolve once in four hours. Concentric with the minute-wheel, and attached to it, is a pinion, having a hole through their common centre, through which passes a stud fixed on the plate. This pinion, having 14 leaves, drives the hour-wheel *m*, of 42 teeth, once round in 12 hours; this wheel is placed over the cannon-pinion by a socket, which has a hole through it for the cannon-pinion to pass through; on this socket is fixed the hour-hand *k*. It will be perceived that by this arrangement the cannon-pinion, minute-wheel, pinion, and hour-wheel, together with the hands, can all be turned backward or forward without affecting the interior mechanism of the watch, simply by the application of a key to the squared end of the cannon-pinion. The assemblage of wheels, &c., thus put in motion is called the *motion-work* of the watch; that between the plates, the *movement*, which we shall next describe. The centre-wheel gives motion to the third wheel-pinion, to which is attached the third wheel G, acting upon the contrate-wheel pinion. On this is placed the contrate-wheel acting in the pinion of the balance-wheel L, which is also called the scape-wheel. We have already explained the mode by which the balance-wheel teeth act upon the pallets, so as to cause an alternating motion in the balance M. One end of the balance-wheel arbor works in a piece called the dovetail, which is inserted in a piece *p*, called the potence, firmly attached by a screw to one of the plates of the watch; the other end works in a piece called the follower, which is inserted in another piece riveted into the plate called the counter-potence, (left out of the figure to prevent confusion). Another part of the potence, called the foot, receives one end of the balance arbor or spindle, called the verge (on which are the pallets); the other end works in a hole in the pin *o*, which passes through the centre of the cock *q q*, which is secured to the upper plate of the watch; the pendulum-spring (also called the regulating-spring and hair-spring) has one end, immediately below the balance, secured to a stud fixed in the plate, and the other pinned fast to a small collet, which goes spring-tight unto the axis of the verge, and is seen just under the balance. *Figs.* 13, 14, and 15, represent some of the parts separately. *Fig.* 13 shows the main-spring in a relaxed state as it would appear out of the barrel; to which, when in, one end of it is attached, the other being held by a hook in the arbor of the barrel, which comes through the plate, as shown in *fig.* 12, and is kept from turning by a ratchet and click. The spring is wound up by the chain acting on the barrel and pulling it round, which operation is performed by turning a key placed on the squared end of the fusee-arbor. The effort of the spring to unbend itself after being wound up causes the barrel to revolve in a contrary direction to that in which it moved whilst winding up, and thereby gives motion to the fusee, and with it the fusee-wheel and the rest of the train. *Fig.* 14 represents the barrel and fusee, with the chain attached. *Fig.* 15 shows the balance-wheel, balance, and verge, with the hair-spring attached to it.

Fig. 13.

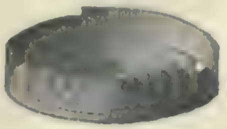


Fig. 14.

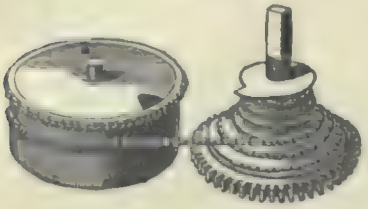
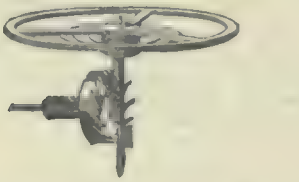


Fig. 15.

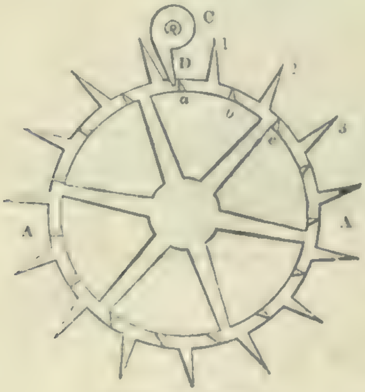


Details of Vertical Watch.

We shall now notice the better kinds of watches, the peculiarities of which mainly depend on the escapement.

The *Duplex Escapement* is shown in *fig.* 16. A A is the scape-wheel, 1, 2, 3, being the teeth of repose, and *a*, *b*, *c* the teeth of impulse, which are triangular, and stand perpendicular to the plane or surface the wheel. C D, the impulse pallet, fixed upon the arbor of the balance, and standing just above the surface of the wheel A A, receives its motion from the teeth *a*, *b*, *c*, &c. After the tooth *a* has passed the pallet C D, the tooth *b* comes in contact with a small roller made of ruby, and placed on the lower part of the axis of the balance, where it remains till the balance is brought back by the balance-spring to such a position that the notch, shown by the dotted line in the ruby roller, will allow the tooth 1 to enter it, and thereby pass the balance-arbor, or escape, which it does by the wheel A A being constantly urged in the direction from 3 to 1. As soon as tooth 1 escapes from the notch, tooth *b* gives a fresh impulse to the pallet C D, and the act of escapement is thus repeated; the wheel moving forward one whole tooth, and the balance making two vibrations for each impulse given by the upright teeth.

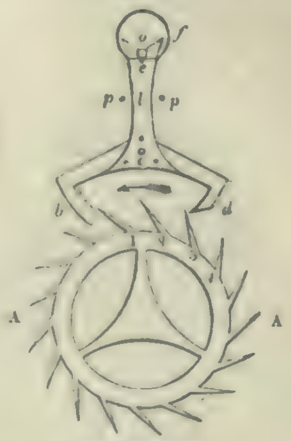
Fig. 16.



Duplex Escapement.

Another effective variety, the *lever escapement*, is shown in *fig.* 17. The lever *l* is placed on the pallets in a position at right angles to that in which it is usually placed in a watch, by which means we think the principle will be more apparent to the general reader. A A is the scape-wheel moving in the direction of the arrow; *b d* the pallets, whose centre of motion is *c*. To the pallets is pinned the lever *l*, in which is the guard pin *e*, pointing upwards from the lever *l*; the roller *f* is fixed on the axis of the balance, and stands just above the lever *l*, having a piece cut off from its circumference to allow the guard pin *e* to pass and repass the roller, which it does when the escape takes place. *o* is a ruby pin fixed in the roller, and pointing downwards through the notch in the end of the lever *l*. When the balance is quiescent, the pin *o* is in the notch in the end of the lever *l*, and the guard-pin *e* in the position shown in the figure, where the tooth 1 acts on the pallet *b*, which causes the balance to vibrate. The guard-pin *e* proceeds a short distance to the right of its present position, and the lever is prevented from returning by the guard-pin *e* coming in contact with the circular edge of the roller. When an impulse is given by a tooth to the other pallet *d*, the lever *l* impels the ruby pin *o* to the left hand, where precisely the same effects take place with regard to the guard-pin *e*, &c., as have been already described. If the pallets *b* and *d* were of the form shown by the dotted lines (which are supposed to be circular arcs concentric to the centre of motion *c* of the pallets), it is evident it would be a perfect dead beat, like the clock escapement previously described; but in order, after the escape has taken place, that the guard-pin *e* may be retained at a small distance from the roller, that part of each pallet on which the tooth rests when it falls on the pallet is taken off, as shown in the figure; and as the faces of the wheel-teeth are considerably undercut, the wheel advances a small distance, after having fallen on that part of either of the pallets which is within the dotted line. This further advance of the wheel draws the pallet down towards the centre of the wheel, and thereby keeps the guard-pin *e* at a slight distance from the edge of the roller *f*. As soon as the balance has performed so much of the returning vibration as to bring the ruby pin *o* into the notch in the lever, the momentum of the balance, acting through the medium of the ruby pin *o* upon the lever, moves it a short distance, and thereby lifts the pallet outwards from the centre of the wheel and unlocks it. During this unlocking the wheel retrogrades (before it can get upon the face of the pallet to give a fresh impulse) just as much as it had previously advanced after falling on the pallet. By this retrograde motion the tooth gains the inclined plane or face of the pallet, and gives a new impulse; and the same process is repeated by another tooth on the opposite pallet. *p p* are two pins, called banking pins, against which the lever *l* presses when locked, and which prevent the guard-pin *e* from being drawn too far away from the edge of the roller *f*, when the locking takes place.

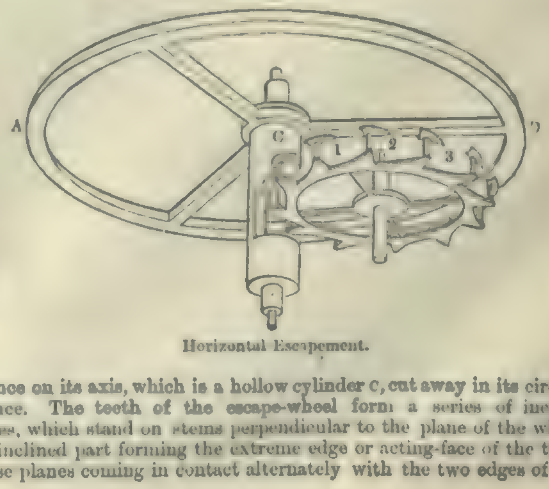
Fig. 17.



Lever Escapement.

In *fig.* 18 is shown a *horizontal escapement*. A B C represents the balance on its axis, which is a hollow cylinder C, cut away in its circumference. The teeth of the escape-wheel form a series of inclined planes, which stand on stems perpendicular to the plane of the wheel; he inclined part forming the extreme edge or acting-face of the tooth. These planes coming in contact alternately with the two edges of that

Fig. 18.

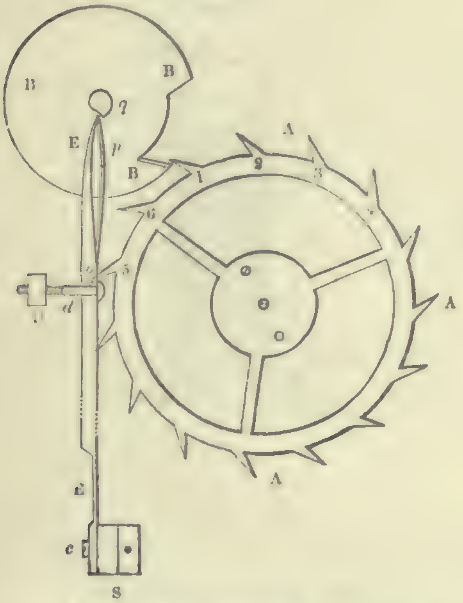


Horizontal Escapement.

part of the cylinder which has the least portion of its circumference taken away, when a tooth is in the cylinder, the point rubs against the internal surface until the balance by its vibration gets into such a situation that the inclined plane can act upon its edge. It then impels the cylinder in the direction from D to A; until the highest part of the plane escapes from the inside of the cylinder, and the next tooth falls upon the outside. This tooth continues to rub until the balance completes its vibration and has returned so far as to permit the point of the tooth, which has been rubbing on the outside of the cylinder, to get upon its edge, where it gives impulse to the cylinder; and when its heel escapes, the point falls on the inside of the cylinder, and the former process is repeated. 1, 2, 3, &c., are teeth of the horizontal or scape-wheel, one of which is seen inside the cylinder; the dotted lines represent the face or inclined plane of the tooth, which is just coming in contact with the edge of the cylinder. The direction of the motion of the wheel is from 1 to 3; the proportion of the cylinder to the wheel is such, that a tooth of the wheel, when in the cylinder, may just have sensible shake; and the outside diameter must be sensibly less than the distance between two teeth.

The *detached escapement*, such as is used in a modern chronometer, is shown in *fig.* 19. A A A is the scape-wheel, made either of brass or steel, the teeth 1, 2, 3, 4, &c., of which are considerably undercut on the face. The steel-roller or main-pallet B B B, which is fixed on the arbor of the balance, has an opening in it, the face of which is also much undercut as shown near B, and has set in it a piece of hard stone, such as a ruby, for the points of the teeth to act upon. S is a stud firmly fixed to one of the plates to which the detent-spring E E is secured by a screw *c*. This spring is made extremely slender and weak in the part E near the stud; and it is only by the yielding of this thin part of the detent-spring that any motion can be given to the detent for the purpose of unlocking the wheel; so that some part of this spring may be considered as the centre of motion of the detent. D is a stud also fixed to the plate of the watch, into which is inserted a screw *d*, against the head of which the detent rests. *o* is a ruby pin inserted in the detent, pointing downwards from the detent; so that one of the teeth of the wheel which is supposed to pass under the detent may rest on the pin; and in this state the wheel is said to be locked. To the inner side of the detent is attached a very delicate spring, called the lifting-spring, which rests upon and extends a little beyond the end of the detent. Concentric with the main pallet, and just above it, is a small lifting-pallet *q*, which should be flat on its face or lifting-side, and rounded off on the other side. In the position given in the figure, the lifting-pallet *q* is just coming with its face in contact with the lifting-spring *p*; which in the course of vibration it lifts, and with it the detent (on whose point the lifting-spring presses), so as to raise the pin *o* clear of the wheel-tooth 5. By the time the wheel is free from the ruby-pin, the main-pallet has advanced so far as to be ready to receive an impulse from the tooth 1; and before the tooth escapes the lifting-pallet *q*, parts with the spring *p*, and the detent resumes its place on the head of the screw *d*. In this position the ruby-pin receives the point of tooth 6, as soon as tooth 1 has escaped from the ruby-face of the main-pallet B B B. The balance, having performed this vibration by the impulse given to the main-pallet, returns by the force of the balance-spring, and with it the lifting-pallet *q*. The rounded side of the latter pressing against the lifting-spring *p*, raises it from the detent, and passes without disturbing the detent, which is not again lifted till the balance has completed the present vibration, and returning for the next. In so doing it again brings the face of the lifting-pallet in contact with the lifting-spring, which (with the detent) it raises, and the act of escaping again takes place; the balance making two vibrations for every impulse, as in the duplex. This escapement, which was invented by Earnshaw, is one of the best for simplicity and for performance.

Fig. 19.



Detached Escapement.

The name *repeating-watch*, or *repeater*, is applied to a watch which, in addition to showing the time on a dial, is supplied with mechanism by putting which in action the wearer is enabled to ascertain the time within certain limits. We have shown, in describing an eight-day clock, how the number of blows given by the hammer to the bell is made to correspond with the hour denoted by the hands of the dial; and also that, by pulling a string, the clock will at any time repeat the hour last struck. But this will not be the case where the minute hand has approached within about ten minutes of twelve o'clock, for from that time till the hand comes to twelve the clock is *on the warning*, and is in such a position that it cannot strike at all. This defect is remedied in *repeaters*. Most repeaters are watches which are capable of striking on a bell or spring the hours and quarters; but there are others which also strike the minutes, and these by way of distinction are called *minute repeaters*. In a repeater, besides the going-train and the motion-work, there is an additional train of wheels between the frame-plates, called the *runners* or *little* wheel-work, or sometimes the *repeating-train*. This train serves the purpose of regulating the rapidity with which the successive blows shall be given to the bell, and consists generally of five wheels and five pinions. The last pinion in the train, performing the office of a fly-wheel, is generally called the fly-pinion; and, when the striking is regulated to its ordinary rate, makes about two hundred revolutions to every blow of the hammer. The chief use of these intricate pieces of mechanism is to furnish the means of knowing the hour of the night in the dark.

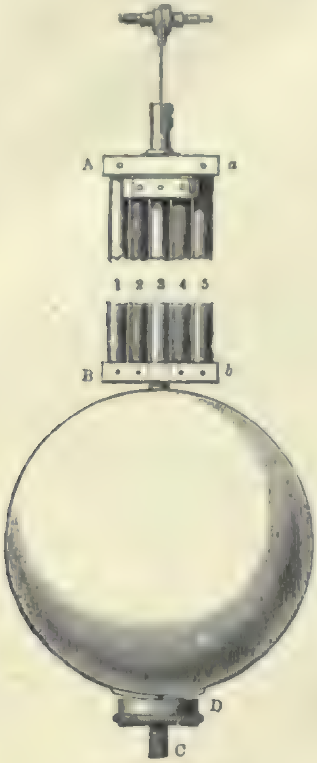
All the more delicate pivots of chronometers, and of the better kind of watches, work in jewelled holes, which will be found described under JEWELLING.

Pendulum Clocks.—We now arrive at the consideration of those horological machines which receive their regulating adjustment by means of the pendulum.

The sensible equality of the oscillations of a weight suspended by a string or wire was first applied as a regulator to a clock by Huyghens about 1657. The successive improvements in the escapement, which sustains the motion of the pendulum and records its vibrations, and those in the pendulum itself, which secure a perfect equality in the duration of each oscillation, have finally produced the astronomical clock, the most accurate machine which man has hitherto constructed, and one of the most essential instruments in a modern observatory. We shall suppose that the dead-beat, or Graham's escapement, is that adopted. The pallets P Q, *fig.* 11, have motion on an arbor which passes through *p*, and has its pivots resting in holes in the clock-frame. A slender bar or wire, called the *crutch*, is attached to this arbor, and a notched piece projecting outwards and backwards from the crutch clasps the rod of the pendulum. The pendulum is hung from a cock at the back of the frame, and moves with the crutch. In a well-made clock, the error arising from expansion from temperature is the most considerable, and is that which must be guarded against. Before explaining more accurate and costly contrivances, it will be well to point out one recommended by Mr. Francis Baily. ('Mem. Astron. Soc.,' vol. i., p. 381.) Take a cylinder of lead about 14 inches long, and pierced through its axis, as a bead, with a hole large enough to admit freely the rod of a wooden pendulum. This hollow cylinder rests on a nut, which works on a screw in the continuation of the rod below. The rod itself, from the centre of motion to the nut, will be about 46·0 inches. As it is easier to cut the cylinder shorter than to lengthen it, and as the expansion of the spring is not allowed for, and that of the wood is somewhat uncertain, it will be better to make the leaden cylinder an inch longer for a first trial; but even if the pendulum should turn out to be *under* compensated, an additional ring of lead may be added, above or below, of the thickness required.

To the best clocks it is usual to apply either the gridiron pendulum of Harrison (which was once chiefly used in England, and is still in repute abroad), or the mercurial pendulum of Graham. The annexed figure (*fig.* 20) is not exactly the pendulum as arranged by Harrison, but accords with his principle. The steel rods 1 and 5 are pinned into two brass cross-pieces, A*a*, B*b*. The zinc rods 2 and 4 are pinned below into B*b*, and carry a cross-piece above, into which the steel rod 3 is pinned. Rod 3 passes freely through a round hole in B*b* (this is shown by dotted lines), and is tapped into a screw below; the bob rests upon the nut, which works on the screw. The steel rods 1 and 5 expand downwards, the zinc rods 2 and 4 expand upwards, and the steel rod 3 downwards; and it is possible so to adjust their lengths (the expansion of zinc being more than double that of steel) that the effects of the expansion downwards and upwards shall have no effect on the length of the pendulum or time of oscillation. Harrison used brass instead of zinc for the upward expansion; and in order to produce a perfect compensation, was forced to use four more rods, a second pair of brass to expand upwards, and another pair of steel to expand downwards: nine in all. The foreign artists use zinc, which requires only five bars, less workmanship, and only one nice fitting. One or two flat brass horizontal bands are attached to 1 and 5 to keep the zinc rods in their places.

Fig. 20.

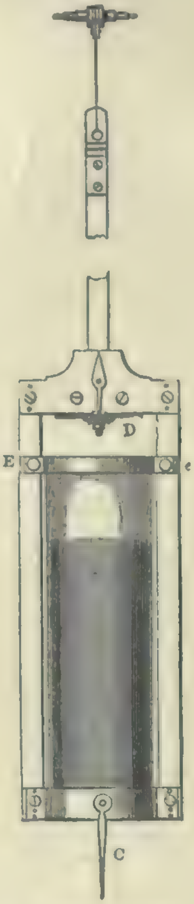


Gridiron Pendulum.

In Graham's pendulum, a glass jar, partly filled with mercury, is supported in a sort of steel stirrup. The pendulum rod passes through the top of the stirrup, and is held by a nut and adjusting screw at D, *fig.* 21. The height of the mercury in the jar is about 6·7 inches; but this will vary somewhat with the diameter of the jar, the substance of the rod and frame, and perhaps the variable expansion of the steel rod. The compensation can be altered, and finally perfected, by the astronomer.

Mr. Dent has recently made many improvements in the mercurial pendulum. One consists in the use of a cast iron instead of glass cistern for the mercury; another in the attachment of the cistern directly to the pendulum-rod; a third, in the prolongation of the rod nearly to the bottom of the cistern; and a fourth, in giving impulse to the pendulum at or nearly at the centre of percussion. If an escapement could be contrived which gave its impulse to the pendulum at the middle point of its vibration, and was wholly *detached* from it at all other times, such an escapement would be perfect; and escapements are almost to be considered good or bad as they approach this character. Huyghens proposed a most ingenious contrivance, namely, that the upper part of the pendulum, which he made of two parallel strings, should wrap and unwrap on two cheeks, which being shaped as cycloids, caused the bob itself to describe a cycloid. Now it is a property of this curve that all arcs are described in the same time, so that Huyghens's construction was perfect in principle; it had, however, many difficulties in practice. Instead of suspending the pendulum by a perfectly flexible string, or on a knife-edge, when the motion must be in a circle, the top of the rod may be made to end in a flat spring, which has certain advantages. Mr. Frodsham has found that a spring of a particular strength rendered the oscillations of a pendulum of a certain weight isochronous, and that a considerable alteration in the length of the spring did not affect this quality of isochronism. This may perhaps be explained by supposing the lower part of the spring not to have acted when it was longest, but to have always preserved its rectilinear form. There is an investigation of the effect of atmospheric pressure on the rate of a transit clock at the Armagh observatory, in the 'Mem. Ast. Soc.,' vol. v., p. 125. The author, Dr. Robinson, assumes that the variations of a clock from a constant rate are expressed by the sum of two terms, one depending on the temperature, the other on the pressure of the atmosphere shown by the barometer. The isochronism of the spring is supposed, or that the effect of any change in the arc depending on the above two causes is already expressed in the terms. When the error in the compensation for temperature is determined, this can readily be rectified by altering the quantity of mercury in the jar. As the effect of time is generally to produce a falling off in the arc, a small addition to the clock weight might be made from time to time, so as to bring back the pendulum to its primitive arc, until the clock is cleaned, and its action restored that way. Where the clock is much exposed to variations of temperature, it should be enclosed in a second covering or closet.

Fig. 21.



Mercurial Pendulum.

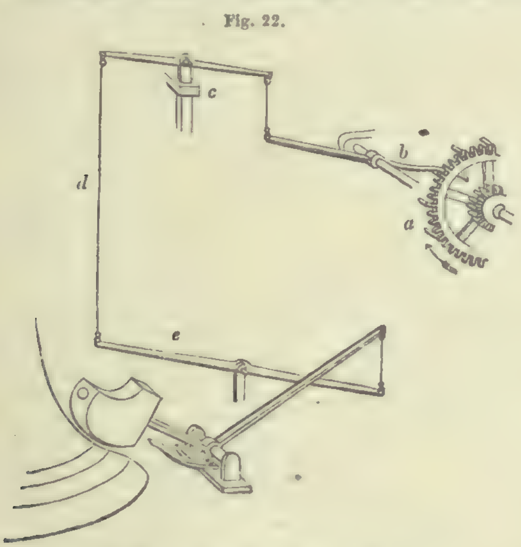
To bring a clock to time, first make it nearly right by the adjusting screw D, but let it have a losing rate, which must be determined by observation after the interval of one or more days. Suppose it is losing 3^s a day. Put a weight, which has been carefully ascertained, say 200 grains, upon the plate which covers the jar (E *e* in the mercurial pendulum, in the gridiron pendulum anywhere near B *b*), and find the fresh rate of the clock by observation. Let it now gain 10^s a day. Then, as 200 grains cause a gain of 13^s a day, 15·4 grains will alter it 1^s per day, and, replacing the 200 grains with a weight of 46·2 grains, will bring the clock to time. The final adjustment of the compensation can be best accomplished when the clock has gone several months, and when the gain or loss in two of the warmest months in the year is compared with the gain or loss in two of the coldest.

For the mathematical and physical principles which govern the action of the pendulum, we refer to PENDULUM.

An *astronomical* clock, such as those used in observatories, is the best example of a pendulum clock, comprising all the most refined means of adjusting the isochronous movements of the pendulum to the measurement of small intervals of time. *Turret* or *church* clocks, however, are commercially of more importance, and of these we must now say something.

Turret-clocks differ from other machines employed for measuring time, not only in their greatly superior size, but also in the arrangement of their parts, and in the circumstance that they are usually make to strike the hours, and often the quarters also, upon large bells. They are also occasionally connected with machinery for chiming whole tunes at certain intervals upon a set of bells which, when mounted in a church tower, are so hung that, by disconnecting the hammers of the chimes and striking apparatus, they may also be rung in the ordinary manner by means of ropes. One of the peculiarities of a turret clock consists in the circumstance that it is frequently required to indicate the time upon as many as four different dials, on the four external faces of the tower in which it is mounted. This apparently difficult matter is accomplished in a simple and beautiful manner: by placing the clock in or near the centre of an apartment either on a level with the external faces, or above or below them, and causing the motion of the minute-hand axis to be transmitted by bevil-gear to a vertical rod, the opposite end of which carries a horizontal bevil-wheel nearly on a level with, and situated centrically with reference to, the four external dials. The motion of this central wheel is communicated by four vertical bevil-wheels of the same size and number of teeth, ranged round its circumference, to four horizontal rods, the opposite ends of which, passing through the several dials, carry the four minute-hands. At the back of each dial is a series of wheels and pinions, constituting the motion-work; while the movement of the hands and that of the striking apparatus are provided for by separate trains of wheel-work, each of which is impelled by its own moving power. In a turret-clock, the moving power is supplied by the descent of a weight, regulated in the case of the movement, or going-train, by the oscillations of a large pendulum, and in that of the striking-train by the resistance of the air to the rapid revolutions of a fly or fan set in motion by the wheel-work. The weights are wound up (in most cases, weekly) by means of winch-handles and toothed wheels connected with the massive drums round which their ropes are coiled; and, for convenience, they do not descend immediately from the drums or barrels, but in the angles of the tower, or any convenient situation, the course of their ropes being directed by guide-pulleys. *Fig.* 22 may serve as an example of the striking mechanism of turret-clocks in general, although the details of course vary according to the relative situation of the clock and the bell, which in some cases is the reverse of that here represented. In this cut, *a* represents the pin-wheel, by the action of the projecting pins of which upon the end of the lever *b*, communicated through the levers *c* and *e*, the tail of the hammer is depressed, and the hammer-head is consequently raised ready for a stroke. By the continued revolution of *a*, the end of the lever *b*, after being raised to a considerable height, is suddenly released, by which the hammer falls upon the rim of the bell, and the connecting apparatus resumes its original position ready for the next stroke.

Fig. 22.

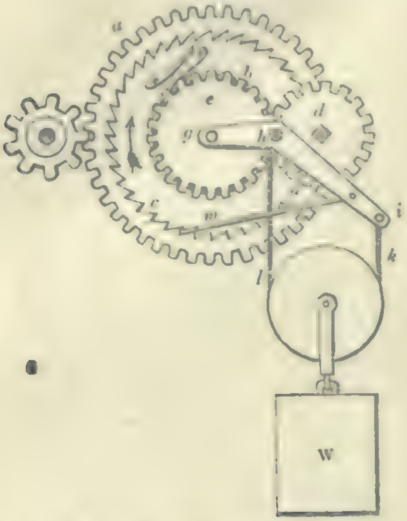


Striking mechanism of Turret-clocks.

Musical chimes, which form a pleasing though not very common addition to the mechanism of turret-clocks, require the addition of another train of mechanism, somewhat like that which constitutes the striking-train; inasmuch as it is perfectly at rest for considerable periods of time, and is brought into action only at certain predetermined intervals by the action of the going-train of the clock upon a detent. The mechanism of the chimes very nearly resembles, on a large scale, that of a musical snuff-box; levers connected with hammers which strike upon a series of bells, being substituted for the springs which in the musical snuff-box are caused to vibrate by the projecting pins on the revolving barrel.

Owing to the very limited demand for turret-clocks, and their great durability when well made and carefully preserved, the business of making them is confined to very few establishments, and has hardly been systematised into a manufacture. Every clock being, in ordinary cases, made individually, and with comparatively little aid from machinery, turret-clocks have been very expensive, and in many cases inferior in accuracy of workmanship to many far simpler, cheaper, and more common machines. The late Mr. Dent, when engaged about the year 1843 by the Gresham Committee to make a turret-clock, of unprecedented perfection, for the new Royal Exchange, under the superintendence of Mr. Airy, the astronomer-royal, determined to meet this deficiency by establishing a clock-factory supplied with all the aids and appliances of modern ingenuity, in which the several parts of a turret-clock should be produced as far as possible in the same way as the component parts of a power-loom or other machine manufactured upon an extensive scale. In the Exchange clock, he adopted the use of a simple but strong cast-iron framing, in which every strain is so completely self-contained, that the operation of fixing the clock in its destined position is one requiring but little skill, scarcely any adjustment being required beyond the fixing of the frame on a firm and level base. Another, and a more unusual feature, which Mr. Dent (borrowing from the French) has introduced into the turret-clock manufacture, although it is not adopted in the Exchange clock, is the use of cast-iron wheels for the striking-train. After many experiments, Mr. Dent came to the conclusion to use for the wheel-teeth (the driver) the epicycloidal curve, and for the pinion (the driven) the hypocycloidal curve, putting nearly the whole of the curve on the wheel-teeth. He also applied this theory to the lifting of the hammers, both for the striking apparatus and the chimes, by using projections of an epicycloidal shape instead of the ordinary round pins in the pin-wheel. Clock-wheel cutters had heretofore paid very little attention to the geometry of the wheel-teeth. Among the other important features of the Royal Exchange clock, which are applicable to all others of similar character, whether constructed with its peculiar contrivances for insuring perfect accuracy or not, we may mention the use of hollow iron drums instead of wooden cylinders for the driving-barrels, and the use of wire instead of hempen ropes for suspending the weights. Another important arrangement is the driving of the hands of the clock, and the raising of the hammers of the striking apparatus, directly from the axis of the driving-barrel, without the intervention of any wheels and pinions. In their determination to secure a public clock of unexampled accuracy, the Gresham Committee required that the Exchange clock should have a compensation-pendulum, and that it should be so constructed as not only to show perfectly correct time upon the dials, but also to tell it with accuracy by making the first stroke of the hour upon the bell true *to a second.* This difficult work is provided for by an arrangement for moving the lever and hammer to nearly the utmost degree required before the time of striking; and causing the end of the lever, which is formed in a peculiar manner for the purpose, to remain poised delicately upon the rounded point of the projecting tooth of the pin-wheel until the moment of striking, when it is instantaneously released. The pendulum is of a comparatively simple construction, which appears well adapted for large clocks. The centre rod is of steel, and is sufficiently long to pass completely through the bob or weight, which, however, is not immediately attached to it. Upon the bottom of this rod is fixed a nut, by turning which the length of the pendulum may be nicely adjusted, and upon this stands a hollow or tubular column of zinc, through which the steel rod passes freely. On the top of the zinc column is a metal cap, from projecting portions of which descend two slender steel rods; to the lower ends of these rods the weight, which is a hollow cylinder of iron, capable of sliding freely upon the zinc column, is suspended. Thus, while both the central steel rod and the two smaller steel rods by which the weight is suspended, expand *downwards* upon any increase of heat, the position of the weight in reference to the point of suspension of the pendulum remains nearly the same; because the zinc column, though shorter than the central steel rod, expands, owing to the different nature of the metal, to an equal extent *upwards*, and consequently raises the weight just as much as it is depressed by the lengthening of the steel rod. The delicate setting or adjustment of the pendulum was effected by a contrivance suggested by Mr. Airy. The escapement is of the *remontoire* kind. The impulses imparted to the pendulum are not given immediately from the large going-train of the clock; seeing that this impulse is exposed to variations of force and resistance. They are given by a small secondary train, set in motion by the descent of a ball or weight, which is itself raised at intervals of twenty seconds by the mechanism of the going-train. The action is therefore very similar to that of a *remontoire-spring;* which, as used in some horological machines, is a small spring employed only to set the escapement in motion, it being itself wound up at very short intervals by the going-train, which receives its impulse from the prime mover. The escapement is Graham's dead-beat escapement, and has the pallet jewelled with large sapphires. In this clock has been introduced a beautiful *maintaining-power,* or contrivance for maintaining the motion of the wheels during the time of winding up; it was invented a few years earlier by Mr. Airy for the clock-work of the great Northumberland telescope at the university of Cambridge. In *fig.* 23, *a* represents the first wheel of the clock, which is mounted, as usual, upon the axis of the rope-barrel *b;* with a ratchet and click so arranged that the two must turn together whenever the rope-barrel is turned, by the action of the weight W, through the line *l,* in the direction indicated by the arrow. When the rope-barrel is turned in the opposite direction, to wind up the weight, by the action of a windlass on the axis of the wheel *d,* which engages the toothed wheel *e* on the axis of the barrel, the wheel *a* will not turn back with the barrel: *f* is the pinion which is turned immediately by connection with the first wheel *a;* and both this and the winding-wheel, or pinion, *d,* have their axes mounted in the plates of the clock-frame. The axis of the barrel and first wheel *a,* instead of being thus mounted, is attached to what may be termed a lever-frame, one side of which is seen in the cut at *g*, *h*, *i*; the lever frame itself is pivoted to the clock-

Fig. 23.



Airy's maintaining-power Fusee.

plates at *h*. To the end *i* the end of the line *k*, *l*, is attached, after passing under a running pulley attached to the weight W. *c* is an internal ratchet on the first wheel *a*, acted upon by the long click *m*, which has its opposite end attached to the lever-frame near its extremity *i*. While the clock is going in the ordinary way, the descent of W causes that part of the line marked *l* to turn the barrel in the direction of the arrow, carrying with it the first wheel *a*, the internal ratchet of which slips under, without being affected by, the click *m*. Under these circumstances the action of the weight W (through the line *l*), and the resistance of the pinion *f*, produce a certain pressure on the lever-frame at *g*; this causes the end *i* to assume a determinate position, in which it remains without motion so long as the weight continues to descend, and consequently to draw down the line *l*. But so soon as, by the operation of winding up the clock, the pressure upon *l* ceases to operate, the stress of the weight upon the portion of the line marked *k* causes the end *i* of the lever-frame to be depressed, and the click *m*, which is connected with it, to be thrust against the internal ratchet *c* with sufficient force to maintain the action of the first-wheel *a*, which turns as it were in one piece with the lever-frame round the axis *h*; thereby producing a pressure upon the pinion *f* exactly corresponding, if the axis *h* corresponds with the point at which the strain of the line *l* is applied to the rope-barrel, to the pressure which is exerted during the ordinary action of the machine.

There is one turret clock which has acquired much notoriety, on account of its size and cost, and of the extraordinary amount of controversy to which it has given rise during the long period of sixteen years; namely, the clock for the new Houses of Parliament at Westminster. In 1844 Sir Charles Barry applied to Mr. Vulliamy for plans and estimates for a clock that would strike the hours on a bell of eight to ten tons, chime the quarters upon eight smaller bells, and show the time on four dials of 30 feet diameter each. How it arose that the clock was made by Mr. Dent instead of Mr. Vulliamy: that a non professional man, Mr. E. B. Denison, became intimately mixed up with the subject: that the plans underwent numerous modifications: and that it was not till 1859 that the clock was actually fixed in its place—it would be wearisome to tell. It cannot be said that even now (March, 1860) the clock is really finished, owing to the unfortunate failure of the great bell (for which see BELL). The chief features of the mechanism are as follow. The going part is arranged for winding-up once a week; but the striking apparatus goes for seven and a half days, to allow for slight delays; and even a delay of one whole day, though it would stop the striking, would not stop the going, the latter being arranged for eight and a half days. The ponderous weights hang down a shaft 160 feet deep. Schemes have been proposed for employing both steam power and water power to wind up the clock; but at present manual power only is employed, and a most laborious duty it is. The pendulum is 15 feet long, and weighs 680 pounds; it is formed of an exterior iron tube 4 inches in diameter, with a compensating inner tube of zinc. It is a two-seconds' pendulum, with a swing or vibrating arc of 14 inches; a small weight of only one ounce, placed on a particular part of the apparatus, will alter the rate of the clock one second per day. The hammers of all the bells [BELL] are (or rather, are intended to be) worked by their levers or handles catching against cams on the edges of wheels; the great or hour-bell being worked by eighteen cams on a wheel 37 inches in diameter. On the four sides of the clock-tower are dial rooms, each an apartment of large size, traversed by mechanism which communicates motion from the clock to the hands. There is at Mechlin a larger clock dial than those at Westminster; but there is no second example of a clock with four dials 22½ feet in diameter, and provided with minute hands as well as hour hands. The frame-work of each dial, weighing no less than 4 tons, and including the quarter-hour and minute subdivisions, is of cast iron. The hour figures are 2 feet high and 6 feet apart; and the minute marks are 14 inches apart. There is a *remontoire* apparatus, to give a *visible* motion of the long hand every half minute, when the point of the hand makes a sudden leap of 7 inches. The hands weigh more than 2 hundredweight the pair; the minute hand being 16 feet long and the hour hand 9 feet. In order that (when all is completed) the indications of the clock may be visible at night, the framework of each dial is fitted in with opal or enamelled glass; provision is made for sixty gas jets behind the dial; and the clock itself will turn on and off the gas, according to the length of night at different seasons of the year.

Electrical and Illuminated Clocks. So numerous have been the novelties in the clock and watch manufacture within the last few years, that the bare enumeration of the names of inventors would occupy a considerable space. We need only, however, notice electrical and illuminated clocks.

The hopes once entertained concerning *electrical* clocks have scarcely been realised. These ingenious machines are not yet largely employed in our great centres of business. There are two kinds, which may be distinguished as electrical *dials* and electrical *clocks* proper. An electrical dial is a clock-dial, without any body belonging to it. There is a standard clock at some other place, such as the Observatory at Greenwich; there is an electric wire connecting the standard clock with the index hands of the dial; and there is apparatus for sending a galvanic current through the wire at certain equidistant intervals of time. The result of this arrangement is, that the dial-hands make a leap over a small portion of their circular course, whenever a current passes through the wire; and the figures marked on the dial give a time-value to this movement. The interval of the shocks may be a minute, half-minute, or any other amount chosen. It is quite possible to make the hands mark seconds' movements, to correspond with the pendulum-beats of a standard-clock; but in practice it is found better that the long hand should only make half-minute jumps. An electric *clock*, in the proper sense of the term, is one that carries its source of power with it, independent of any conducting wire from another building. Various modes of effecting this have been devised by Shepherd, Dent, Airy, and others. In the first attempts, electricity was employed to impel the pendulum itself; but it was afterwards found better to apply the power in raising a small weight, which may then work the pendulum after the manner of a gravity escapement. In Shepherd's Magnetic Striking Clock, the vibrations of the pendulum are caused by the repeated impulses of a fine spring: the attraction of an electro-magnet being employed solely to relieve the pendulum from the action of the spring during the return or reflex vibration. The hands are moved by separate electro-magnets, the circuit of the wires being completed and broken by the pendulum as it swings. The number to be struck is regulated by a locking-plate divided in the usual way, the hammer being moved by the direct action of an electro-magnet. Electrical clocks or electrical dials are used in astronomical observatories, and by telegraph companies, but very little in other quarters.

Intimately allied with this subject is the action of *Electric Time-balls*. These are contrivances for showing exact time *once a day only*, and in a manner to be visible throughout a whole district. The interval may be more or less than one whole day; but this is selected as being most convenient. A large ball is seen to fall at one o'clock in the day; and this fall may safely be taken, by mariners and others, as a guide for correcting chronometers, watches, and clocks. The time-ball at Greenwich Observatory, and that of the Electric Telegraph station in the Strand, may be taken as familiar examples. The Greenwich ball is a basket of wicker-work, covered on the exterior; when it descends, a piston plunges into a tube, compresses the air, and thus, makes a kind of soft cushion which enables the ball to drop without concussion—a small hole in the bottom being left for the air to escape gradually. At a few minutes before one o'clock, the ball is wound up by hand to the top of the staff. At one o'clock, to a single second, the standard clock in the observatory, by means of delicate mechanism, sends a current of electricity which loosens a trigger and lets the ball sink. The time-ball in the Strand, of later construction than that at Greenwich, exhibits many improvements in detail. Several others have since been established at the outports.

The rendering of clocks visible at night is one of the many improvements introduced in recent years. The illumination is effected in many ways. At the Horse Guards in Whitehall, light is thrown on the face of a dial from a gas-flame hidden behind a parapet. The more usual method is to make the dial either wholly or chiefly of semi-opaque glass, and to manage the lighting in the way just noticed concerning the (prospective) arrangements for the Westminster clock. Such dials, however, are not so conspicuous and convenient during the day as those of ordinary construction; and it is difficult to maintain the hands in a well-adjusted condition. A suggestion w made a few years ago for the use of semi-opaque hands and figures on a transparent dial; with gas-lights in a black-cloth lined chamber behind the dial, and reflectors to throw the light on all the surrounding objects except the black cloth. General Perronet Thompson has suggested a night clock, with twelve holes cut in a disc for the twelve hours, and a radial slit near the centre to represent a hand; the disc is to revolve, and gas-lights to be placed behind it. In a fine new turret-clock set up in the Exchange at Leicester, in 1859, the lighting at night is effected by placing two large lenses before the gas-burners, connected by a pierced tube of jets; so as to light one burner from the other, if either should go out during the day-time, when the gas is turned very low. The illumination is evenly diffused over the dial without glare, and without the position of the burners being distinguishable.

Clock and Watch Trade.—We will conclude with a few observations on the manufacture of clocks and watches, regarded in its commercial and industrial features.

So far as concerns our own country, the manufacture is chiefly conducted in and near London, Coventry, and Prescot. In London, the district of Clerkenwell is the head-quarters of the trade. The *movements* of watches are made almost wholly at Prescot and other places in Lancashire; the London workmen only make the other parts, and put the whole together. A Clerkenwell watch-manufacturer is one who buys movements from Lancashire, employs smaller tradesmen to fabricate the other parts, and brings the watches into a finished state. These tradesmen are not mere workmen; they are small master tradesmen. One supplies the motion-work, another the spring, another the escapement, and others the case, dial, glass, &c. These secondary masters subdivide the work to a degree almost incredible. Every kind of escapement has many different workmen specially employed upon it; and so has every kind of motion work, hands, dials, &c.; insomuch that an ordinary London watch passes through considerably more than a hundred hands, even after the movement has been brought from Lancashire. Nearly all the workmen thus employed labour at their own houses: the work being quite of a handicraft character, in which very little machinery is employed. The men acquire considerable skill, each in his particular craft; but it is a system unfavourable for enterprising inventions and cheapening processes, seeing that each man's tact and experience are confined to one very limited range of work. As a movement in the right direction, a Horological Institute was founded in Clerkenwell in 1858—"to develope and improve everything relating to the art, by means of a library of books, a reading-room, a museum of tools and machines or models, the reading of lectures and essays, and the publication of a Journal." The principal makers of church and turret clocks live in London, and manufacture nearly the whole of the machinery on their premises. Prescot exports watch movements to America, as well as supplying the home trade; more machinery is employed in this trade, and to this fact perhaps may in part be attributed the settlement of it in a county celebrated for its delicate machinery.

Switzerland is celebrated for its watch-making. The women and children in Neufchâtel, and some other cantons, learn certain parts of the trade, and find employment in this way, either all through the year, or in the winter, when little out-door work can be done. There is a minute delicacy in Swiss watches which those of England seldom exhibit; and the selling price is such as no English maker can compete with. On the other hand, the *best* English watches are not equalled for strength and accuracy by any others in the world. A London manufacturer, Mr. Bennett, has within the last few years endeavoured, by means of letters, pamphlets, and lectures, to foster the introduction of the Swiss system into England, as a means of increasing the range of employment for women, lowering the prices of watches, and increasing the sale. In the meanwhile, machinery is gradually being brought into the trade in Switzerland and the adjacent part of France. Brukker's small brass clocks, saleable in London retail at only five shillings each, would be a commercial impossibility without the aid of machinery. At Besançon, machine-made watches are now produced in large numbers; the product in 1848 was about 28,000; and in 1856 it reached 160,000, worth about 320,000*l*.

America has organised a very large system of clock manufacture—quite on the factory system—chiefly in Connecticut. There is one company which employs 250 hands in a compact factory; many of the operatives are boys and girls; and the product is 600 clocks per day. Much wood-work is employed in the cheaper American clocks; but machine-stamped brass clocks are also manufactured very largely. Dr. McGowan, United States consul at Ningpo, wrote home to his countrymen in 1853, giving some curious details concerning the clock-trade in China: and offering hints whereby America might successfully open a market in that quarter.

HORSE POWER. A term used in mechanical engineering to express the unity of comparison of the power of steam, or water power, machines, which is based upon the assumption that a horse is able on the average to perform a certain definite quantity of work within a given time. Constructors of engines differ in their estimates of the value of an average horse power, some reckoning it to be equal to 27,500; some to 29,000; and others to 33,000 lbs. raised one foot high per minute. The latter estimate was the one adopted by Watt; and it is also the one most generally followed both by English and foreign constructors. On this basis a horse power is said to represent a load, in pounds, raised one foot in vertical height, of 550 lbs. per second; 33,000 lbs. per minute; or 1,980,000 lbs. per hour; or the effort which 7 men working for a short time could exert.

The formula usually adopted in calculating the horse power of low pressure steam engines is as follows:—Calling the effective pressure of the steam upon the piston (beyond the power required to overcome the friction, and the incidental services the engine is called upon to perform, such as the movement of the feed-pumps, the air-pumps, &c.)—calling this effective pressure, supposed for instance to be 7 lbs. per square inch, A; the diameter of the piston in inches, D; and the velocity of the piston in feet, per minute, V; we have the formula $x = A\frac{\frac{1}{4}\pi D^2 V}{33{,}000}$, or, in round numbers $= \frac{D^2 V}{6000}$. In condensing and expansion engines this formula ceases to apply; for the point in the stroke at which the steam is cut off materially affects the effective pressure; and it is by no means rare to find at the present day that steam-engines will exert a force actually three times as great as the theoretical force indicated by calculation. As the proportions of the various parts of engines and boilers are calculated with reference to the horse power of the engines, this uncertainty in the mode of ascertaining the unity of work is unfortunate, and numerous remedies have been suggested; such, for instance, as the calculation of the force by means of the weight of steam produced. No confidence can, however, be placed in them, and the old formula is still generally followed.

Two very rude empirical formulæ are adopted by some practical engineers for calculating the horse power of an engine, which may sometimes be of convenient application, as furnishing an approximate means of estimating the value, without, however, attaching any precise importance to the indications so given. They are, calling the diameter in inches, a; the number of strokes, b; the length of the stroke in English feet, s; then $\text{HP} = \frac{a^2 \times \sqrt[3]{s}}{47}$; or, $\text{HP} = \frac{a^2 \times bs}{6000}$.

The horse power of a water-fall is really indicated by multiplying the cubic quantity of water falling over the shuttle by the height of the fall and by 62·5—the weight of a foot cube of water being 62·5 lbs. In the best descriptions of water-wheels, however, a very large portion of the real power is lost by the friction of the machinery, and by the passage of a certain portion of the water without its striking the wheel; and in the more unfavourable varieties the loss is so great as to materially modify the calculated results. Thus Mr. G. Rennie calculates that the effective results as compared to the theoretical ones are, for overshot wheels as 27 or 30 to 100; for breast wheels as 45 or 50 to 100; and for undershot wheels as 60 or 80 to 100. Calling then the quantity of water falling, Q; the height of fall, H; and the co-efficient of the real effective power, expressed decimally, C; we have the formula for a water-wheel $\text{HP} = \frac{QH \times 62{\cdot}5}{33{,}000} C$.

As the usual application of the power of a horse is for the purpose of drawing a load on roads, it may be as well to state, that the useful result of such application must evidently depend on the state of the surface of the roads themselves. This branch of applied science has been studied by Gerstner, Parnell, Gordon, &c.; and the results of their investigations are expressed in the following empirical formulæ. Calling the power exerted, estimated in pounds, P; the weight of the waggon, W; the load, w; the co-efficient for the surface under consideration, c; and the velocity in feet per second, v; we have $P = c\left(\frac{W+w}{98} + \frac{w}{40} + v\right)$. On an inclined road, this formula becomes $P = c\left(\frac{W+w}{93} + \frac{w}{40} + v + \frac{h}{l} \times \frac{W+w}{1}\right)$; in which h is the vertical rise, and l the horizontal length of the incline. The value of c is usually given as $= 2$ on a paved road; $= 5$ on a well made broken stone road in a good state; $= 10$ on a similar road when wet and muddy; $= 13$ on a dry gravel or broken flint road; and as $= 32$ on a wet and muddy gravel or broken flint road. Coulomb, and the earlier writers on dynamics, considered that the ordinary power of a horse, at a dead pull, was equivalent to 420 lbs.; and that he was able to exercise the above force most advantageously, when walking at the rate of 3 feet per second. Smeaton gives the useful effect of a horse walking at that velocity as being equivalent to 189 lbs.; this velocity is nearly at the rate of 2 miles per hour; but when the velocity becomes 3 miles per hour, the useful effect falls to 80 lbs. Telford gives 200 lbs. as the actual work of a horse raising a weight over a pulley out of a well, for eight hours in a day, at the rate of 2½ miles per hour; he also says that in a cart, a horse will draw more than 2000 lbs. For more extended statements on this subject, see the article ANIMAL STRENGTH. A great deal of curious information may be likewise obtained upon the subject of horse power as usually exerted, in Gordon's 'Treatise on Locomotion,' 1834. Borgni's 'Traité complet de Mécanique,' 1818, contains, however, the most complete digest of the experiments on the power of men and of animals.

HORSE-RADISH.—*Medical Properties of.*—Horse-radish is a cruciferous perennial herbaceous plant, growing in Alpine meadows, and along the banks of rivers, as well as on the sea-coast in the south and south-eastern parts of Europe, called Cochlearia Armoracia (Linn.) or Armoracia rusticana (Wettereau). The root is the officinal part, and is always obtained from cultivated plants, as it is enjoined to be used in a fresh state. The root is solid, fleshy, tapering, from one to two feet long, and when bruised or scraped into shreds, emits a highly acrid penetrating odour, which causes a secretion of tears when received by the eyes: put in contact with the skin, it speedily causes rubefaction. The taste is more or less acrid, according to the season of the year or the age of the plant; young plants possess much mucilaginous starchy and saccharine matter, by which the pungency is lessened.

The analysis by Gutzet shows its composition to be acrid and very volatile oil, bitter resin, extractive, sugar, gum, starch, woody fibre, vegetable albumen, acetic acid, with acetate and sulphate of lime. A little sulphur also exists in it. The volatile oil is the active principle. This is of a pale yellow colour, heavier than water, and so volatile that a single drop of it can fill a large room with a penetrating odour of horse-radish. In this respect it resembles the volatile oil of mustard. The taste is at first sweetish, afterwards burning and acrid. It has a sensible effect on the brain. When applied to the skin, it causes violent inflammation and rubefaction. It is identical with oil of mustard. [SINAPIS, in NAT. HIST. DIV.] It is sparingly soluble in water; freely in alcohol. The outward application of horse-radish causes vesication; the internal application causes sensible warmth of the stomach, with augmented power of digestion. A warm infusion excites vomiting, in the same way as mustard does. This kind of emetic is useful to rouse the stomach from the insensibility consequent on narcotic poisons being taken, but it must not be forgotten that violent or even fatal inflammation of the stomach may ensue if vomiting do not occur, and the stomach-pump is a more certain means of emptying that viscus.

Horse-radish is well known as a condiment taken with beef, fish, and other kinds of food difficult of digestion. Its powers are heightened by associating it with vinegar, as in the horse-radish sauce.

The officinal preparations are the Infusum Armoraciæ Comp. This, when made with warm water as ordered in the Pharmacopœia, soon spoils, notwithstanding that some compound spirit of horse-radish is added to it. It would be much more advantageous to make it with cold water, especially as its power depends upon a principle of such remarkable volatility. The compound spirit is employed as an adjunct to diuretic and other medicines. Horse-radish scraped down into shreds and digested in red wine forms a Vinum armoraciæ, which is eminently useful in warding off a relapse of intermittent fever, when the employment of it is persevered in for some time. Digested for an hour in vinegar, it is an excellent gargle against hoarseness.

(Dierbach, *Die Neusten Entdeckungen in der Materia Medica*, i. p. 81.)

HOSIERY MANUFACTURE. The principal seat of the hosiery manufacture in England is in the three midland counties of Leicester, Nottingham, and Derby. In the first of these woollen hosiery forms the principal branch of the manufacture, while in Nottinghamshire the material chiefly used is cotton, and in Derbyshire silk goods are mostly made.

The stocking-frame, by means of which this manufacture is carried on, is, next to the common warp and weft loom, the oldest machine in existence applicable to textile fabrics. It was invented about the close of the sixteenth century by the Rev. William Lea, of St. John's College, Cambridge; but a considerable time elapsed before the produce of this frame took the place of the trunk-hose then worn by all who could afford such an article of dress. For this reason Mr. Lea settled at Rouen in Normandy, where his manufacture was carried on under the patronage of Henri IV.; but the assassination of the king and the political troubles brought on by that event caused the abandonment of Mr. Lea's establishment, and that gentleman shortly after died in a state of poverty at Paris.

From the period of its first invention the stocking-frame received no considerable improvement until quite recent times. Frames, however, with a rotatory action, and worked by steam-power, have been successfully brought into use at Nottingham, and bid fair to supersede altogether the use of the old reciprocating engine. The economy in the process of manufacture thus effected is very great. The working of a rotatory machine impelled by steam-power, in which twelve fashioned stockings are made at the same time, requires the superintendence of only one man and a boy; whereas in the old frame but one stocking can be made at once by a single workman. The substitution of steam-power frames for the old hand frames produced at first some distress among the framework knitters; but the great extension of demand which is always found to accompany a considerable cheapening of any manufacture, lessened this evil by causing employment for an increased number of hands. The cotton branch of the hosiery manufacture differs from the woollen and silk branches in the relative proportions of the cost of labour as compared with the cost of the material. In cotton hosiery the cost of labour constitutes from two-thirds to five-sixths of the value of the goods; while in woollen hosiery the labour does not exceed two-fifths of the value; and in silk goods the proportionate cost of labour is still smaller.

It is difficult to describe the processes of this manufacture without the use of many wood-cuts; and even then the routine is not well understood without seeing the machines actually at work. The hosiery or frame-work manufacture is a peculiar kind of interlacing. Instead of being a series of cross threads woven in a loom, it is a series of loops or links, so connected as to possess both strength and elasticity in a remarkable degree. It is a continuous thread which is thus linked around itself; in a way which bears a good deal of resemblance to many kinds of ladies' netting and crochet work. The article made in the stocking frame is not a stocking, but a piece of knitwork cloth, which is afterwards sewn up into the form of a stocking by needle and thread. Hence, there are three kinds of operatives engaged; the *winders*, who put the thread into or on the machine; the *frame-work knitters*, who work the thread up into a knitted fabric; and the *seamers*, who make the stockings out of the pieces thus produced. The winders are generally children, who can each wind thread enough for half a dozen machines; the knitters are men, women, and youths, who hire both the winders and the seamers; and the seamers are women. Some of the stocking-frames are owned by the frame-work knitters; some are let out to the men by the owners, at so much per week for each frame; while other persons are the renters of what is termed a 'shop of frames,' containing eight or ten frames; these, with standing-room to work in, they let to the workmen, at so much per frame per week. The master manufacturer gives out his thread, and the workman returns this thread in the form of stockings, the work being paid for at so much per dozen pair.

We have spoken only of hosiery, but many other articles besides stockings are made of this linked fabric. Gloves, waistcoat-pieces, mitts, pantaloons, drawers, braces, webs, comforters, caps, jackets, leggings, and various other articles—are made nearly in the same way, and of the same material. The processes for worsted, cotton, and silk are nearly analogous; those for silk requiring, however, the greatest care. Some progress, as has been remarked above, has been made towards the manufacture of hosiery by means of steam power.

Ireland is gradually advancing in this as in many other branches of industry. At Balbriggan there is a hosiery manufacture, from which specimens of cotton hosiery are issued, of a degree of fineness such as has never perhaps been equalled; one dozen pairs of ladies' full size stockings weigh only nine ounces. Cotton stockings of a peculiar kind of open work are also manufactured in the same town.

Among various inventions relating to the manufacture of looped and other hosiery fabrics, is one by Messrs. Keeley and Wilkinson. Several threads are here used instead of one, differing in materials and possibly in colour; these are so looped that any one or more threads may be completely enveloped by the other; and the mode of interlacing is such that, in the event of failure of a loop, it does not necessarily cause the general running or failure observed in most hosiery goods under similar circumstances. By this system, gloves or stockings may be composed of three threads, one of cotton and two of silk; the silk being shown both on the outside and the inside, and the cotton hidden between them. The cotton stratum may consist of two threads instead of one. A substitute for expensive silk stockings or gloves is thus produced. Many improvements have also been made in the manufacture of looped fabrics required to be narrow at one end, like braces; the usual way is to sew the material transversely, and then draw the thread so as to give a closer texture to the narrower part; but the frames are sometimes so adjusted as to weave the wide part, and then produce the narrow part with the same number of threads by a change in the action of the mechanism. Another novelty consists in the making of gloves or mitts, in such a way that the inner surface of the knitted fabric shall exhibit a pile or velvet texture. India-rubber is now very ingeniously employed in gloves and other knitted fabrics, to give elasticity and closeness of fit to particular parts. The circular knitting, or hosiery machines, are efficient contrivances for producing garments without a seam; the construction is very intricate; and some are so contrived as to produce a pattern or device as well as to produce the fabric itself.

The hosiery manufacturers of this country, at least those engaged in making cotton stockings, are much interfered with in the foreign trade by the competition of Saxony. At Chemnitz the manufacture of cotton stockings is carried on very extensively. There are large establishments in which circular frames are worked by steam power, with steam presses and steam irons to finish the goods. The women who tend these machines receive little more than 2*s.* per week on an average; but this sum will go as far as 5*s.* in England, as a means of support. The Chemnitz hosiery is exported largely to the United States, where it proves a formidable competitor to English produce.

It has been stated in a former paragraph that the stockingers of the midland counties follow a peculiar system in hiring the frames with which they work. Hence arises a condition of things against which they are always complaining. With the exception of the Spitalfields silk weavers, few artisans in England have more frequently solicited the protection of the legislature than the stockingers or frame-work knitters, especially those engaged in the worsted trade of Leicestershire. The men and their families are always poor, let the state of trade be brisk or slack; they seem bound to their employers by shackles which they cannot throw off; and there is a general tone of despondency in all their communications on the subject. They state that, whatever be the nominal wage for making a dozen pairs of stockings, the stoppages are so great, for frame-rent and other items, that their net earnings, even for adult men, do not exceed 8*s.* or 10*s.*

per week. Among numerous appeals to the legislature, one in 1844 made a considerable impression; it was a petition signed by 25,000 frame-work knitters. The government employed Mr. Muggeridge as a commissioner, to make minute inquiries in the three midland counties. He examined no less than 600 witnesses, and came to a conclusion that the legislature should step in to protect the artisans. All the leading statesmen, however, felt that any interference between employers and employed on a matter of wages lies beyond the functions of the British legislature; and nothing particular was effected. After many years' more complaining, a Committee of the House of Commons investigated the subject in 1857. A volume of 700 folio pages, containing an immense mass of information, was the result of this inquiry; and a few words from the Report of the Committee will suffice to show the singular commercial economy of the trade. Foreign competition, improvements in machinery, and changes of fashion, have tended to lower the wages of those who work on the old hosiery-frames; and this lowering, it is contended, is aggravated by the mode of paying wages. "The middle-man supplies the workman with frames and other machinery, sometimes belonging to himself, and sometimes hired of the manufacturers and other owners. When he settles with the workman, he deducts out of the gross price per dozen of the work performed—first, a sum as rent for the use of the frame; secondly, a sum for winding the yarn, which is a necessary operation; thirdly, a sum to remunerate himself for the use of the premises where the work is performed, and for the standing-room of the frame; and fourthly, a sum for his trouble and loss of time in procuring and carrying to the workman the materials to be manufactured, for the responsibility to the manufacturer for the due return of the materials when manufactured, for superintending the work itself, for his pains in sorting the goods when made, and for re-delivering them at the warehouse of the manufacturer. The manufacture is carried on, in many instances, at the houses of the workmen, and in places distant from the residence of the manufacturer; with no communication between him and the workmen except by the intervention of the middleman." It has become a custom almost universal in Leicestershire, to charge 1*s.* per week rent for a frame, whether it be old or new, and whether it be worked by man, woman, or child; this, it is quite certain, yields a very handsome profit on the capital expended in purchasing the frame. One manufacturer, in 1857, employed 2000 frames, one half owned by himself and the other half by middlemen; but all these frames alike were charged 1*s.* per week to the knitters who used them. It is nevertheless evident that this is a matter with which the legislature can hardly deal; the net actual earnings will, in spite of legislation, depend on the ratio between supply and demand among manufacturers, middlemen, and workmen; it might be altered in name, but not in substance. The Committee of 1857, like the Commission of 1844, failed to produce any legislation on the subject.

A few figures relating to the export and import of hosiery, in 1857, will suffice as an illustration applicable to recent years:—

EXPORTS.

	Dozen Pairs.	Declared Value.
Cotton stockings	1,020,000	£312,000
Cotton hosiery and small wares	..	325,000
Silk stockings	9,300	13,000
Silk hosiery and small wares	..	36,000
Silk and cotton stockings	8,700	6,000
Silk and cotton hosiery and small wares	..	7,000
Worsted stockings	190,000	133,000
Worsted hosiery and small wares	..	215,000

IMPORTS.

	Dozen Pairs.	Average Value.
Cotton gloves	170,000	3½*d.* per pair.
Cotton stockings	450,000	7*d.*, stockings. 4*d.*, socks.
Worsted gloves	6,400	5*d.*

Our exports were chiefly to Australia and the United States; the imports chiefly from the Hanse Towns.

HOSPITAL (sometimes called simply *spital*, from the French *hôpital*), a place endowed for the reception of the sick or support of infirm persons. The first hospital for the sick is said by Monçez to have been founded in the latter part of the 4th century. Hospitals intended merely for the relief of poor and indigent persons in England are peculiarly called *Alms-houses.* At an earlier date hospital signified a place of shelter or entertainment for travellers upon the road, more especially for pilgrims. Spenser in the 'Fairy Queen,' uses the word in this sense:—

> "They spy'd a goodly castle, placed
> Foreby a river in a pleasant dale,
> Which, chusing for that evening's *hospital*,
> They thither march'd."

The Maison de Dieu at Dover, St. John's Hospital at Warwick, and some others, were expressly founded for the reception and entertainment of pilgrims and travellers.

Many of the charitable endowments in England are called hospitals, and are incorporated bodies, consisting of a master, brethren, and occasionally other members. Some of these foundations have also schools attached to them. But the name is now more generally restricted to places for the reception of sick, or wounded persons, and such hospitals are very numerous in the United Kingdom. In London, the chief exceptions are the Foundling Hospital, for the reception of illegitimate children, abandoned by their fathers; Christ's Hospital, an educational establishment for the teaching of classical learning; Chelsea and Greenwich Hospitals for the reception of aged and infirm soldiers and seamen; and Bethlehem and St. Luke's Hospitals for lunatics. Medical and surgical hospitals are established in every large town throughout the kingdom; and in London there are many. The oldest, and perhaps even yet the most important, are St. Bartholomew's, founded in 1122; St. Thomas's, changed from a religious establishment to a medical hospital in 1551; and Guy's, opened for the reception of patients in 1725. These three are supported by endowments, and are very wealthy. All the other hospitals for the sick, in the country, as well as in London, are supported mainly by voluntary contributions. As to the management of their revenues and their general superintendence, hospitals are on the same legal footing as other charities.

The construction of hospitals is a subject which has recently engaged much attention among architects, physicians, and sanitary reformers. The systems which have found the ablest advocates are those known as the *pavilion* and the *corridor;* but a discussion of their respective merits would evidently be beyond our province. It will be enough to say that hospitals for the sick require to be well situated, thoroughly drained, to have the rooms or patients' wards lofty, well lighted and ventilated, and sufficiently and equably warmed. Without these requisites the care and attention of the physician will be either in vain, or materially obstructed.

HOSPITALLERS. Hospitaller, in its literal acceptation, means one residing in an hospital, in order to receive the poor or stranger; from the Latin *hospitalarius*, a word found only in the language of the lower age. The *Knights Hospitallers* were an order of religious formerly settled in England, who took their name and origin from an hospital built at Jerusalem for the use of pilgrims going to the Holy Land, dedicated to St. John Baptist. The first business of these knights was to provide for such pilgrims at that hospital, and to protect them from injuries and insults upon the road. They were instituted about the year 1092, and were very much favoured by Godfrey of Bouillon and his successor Baldwin king of Jerusalem. They followed chiefly St. Augustine's rule, and wore a black habit with a white cross upon it. They soon came into England, and had a house built for them in Clerkenwell, London, in 1100; and from a poor and mean beginning obtained so great wealth, honours, and exemptions, that their Superior here in England was the first lay-baron, and had a seat among the lords in parliament; and some of their privileges were extended even to their tenants. The order was suppressed in England by the 32 Hen. VIII., c. 24, on the ground that the knights sent money out of the kingdom, abetted the usurpations of the pope, defamed the king and his subjects; adding that their revenues would be better spent in the defence of the kingdom.

There were also sisters of this order, of which one house only existed in England, at Bucklands in Somersetshire.

Upon many of their manors and estates in the country the Knights Hospitallers placed small societies of their brethren, under the government of a commander. These were allowed proper maintenance out of the revenues under their care, and they accounted for the remainder to the grand prior at London. Such societies were in consequence called Commanderies. What were commanderies with the Hospitallers were called Preceptories by the Templars, though the latter term was in use with both orders.

The Knights Hospitallers had several other designations. They were at first called Knights of St. John of Jerusalem; afterwards, from their fresh place of settlement, Knights of Rhodes; and after the loss of that island in 1522, Knights of Malta, from the island which had been bestowed upon them by the emperor Charles V. The order still exists under this title, and the chief, or grand commander still resides at Malta.

(Tanner, *Notit. Monast.*; Dugdale, *Monasticon Anglicanum*; Collier's *Ecclesiastical History of Great Britain.*)

HOSPODAR is the title of the persons formerly sent by the Turkish sultan to govern Moldavia and Wallachia, the two provinces north of the Danube. These governors for more than a century were taken from the principal Greek families of the Fanar, such as Maurocordato, Soutzo, Caradja, Morousi, Callimachi, Ypsilanti, &c. They assumed the title of princes, and were addressed as "Most Serene Highness." They held in their respective capitals, Bucharest and Jassy, a numerous court, consisting chiefly of Fanariote Greeks, and were in fact almost absolute sovereigns during the time of their administration. This however might be shortened at the pleasure of the Porte, which often recalled them, and put them to death. At the time of the Greek revolution in 1821 the Hospodar of Moldavia, Prince Michael Soutzo, escaped into the Russian territory, and his relative the Hospodar or Prince of Wallachia was poisoned. The present government of those two principalities is vested in one hospodar, elected separately by the two principalities; who is assisted by representative assemblies, the two principalities having acquired a sort of independence, though acknowledging the suzerainty of the Turkish sultan, whose consent is necessary to the instalment of the hospodar.

HOTBED, a name given by gardeners to a heap of fresh stable litter in a state of fermentation, upon which a glazed box is placed for the cultivation of certain plants requiring heat and moisture in greater quantity than those agents exist in the external air. Formerly hotbeds were more exclusively used for various purposes in horticulture than they now are. This is owing to the perfection to which other means of producing and applying artificial heat have now attained; but still, for the growth of cucumbers and melons, raising seeds of tender annuals, and of other plants, either culinary or ornamental, hotbeds continue to be advantageously employed, as they likewise are for the striking of cuttings.

Hotbeds may be formed of various substances, such as unrotten dung, tan, leaves, or a mixture of these with moist litter; in short, any substance capable of producing and retaining fermentation, and which will admit of being built up so as to support a frame with sashes. The substance however that is most generally used is fresh stable-dung; the preparation which it requires consists in its being thrown in a heap, and also watered, if it contain much dry litter; and as fermentation proceeds it should be turned two or three times, and mixed thoroughly in the process.

The situation in which hotbeds ought to be formed should be dry, open to the south, and well sheltered in every other direction, either by walls backed by high and close-growing trees, or by very close and lofty hedges. Such extensive shelter, though desirable, cannot always be obtained; but some mode should be employed to break the force of sweeping winds. The basis on which the bed is to be formed should be marked out from 4 to 6 inches each way beyond the dimensions of the frame intended to be placed upon it; and if faggots or a layer of brushwood be laid as a foundation, it will admit heat completely under when the bed requires the application of a *lining*, which is a quantity of fresh materials added to the outside, should a diminution of heat require a new supply. The bed is then built of successive layers of the prepared materials, each layer being beaten tolerably compact with the fork as it is laid on, to the height of 4 feet in front, and 4 feet 9 inches at the back: the sides and ends should be quite perpendicular. The top layer should be as free from litter as possible. When thus finished, the frame and lights are placed upon it, and as soon as the violence of the fermentation has diminished, mould is put in; and when the latter has acquired a proper temperature the plants are introduced. Instead of mould, rotten tan, or leaf mould, or sand, is spread over the surface of the bed, when pots containing seeds or cuttings are to be plunged.

As soon as the heat of the bed begins to decline, a *lining* of fresh materials must be applied. This however may be composed of substances that have not undergone any previous fermentation, and may consist of fresh stable-dung, merely shaken up as it is placed against the sides of the bed, or of grass mowings, or of leaves, or of a mixture of such substances.

A bed formed of well-prepared materials, and raised to the height above mentioned, will be sufficient for any purpose for which a strong bottom-heat is required; but a very mild bottom-heat is frequently all that is wanted. In this case the bed is made lower and more compactly beaten or trodden. Substances that ferment violently are likewise excluded from its composition.

It sometimes happens that, notwithstanding every precaution with regard to its formation, a hotbed will become too hot for plants or seeds that may have been placed above it. In this case the only remedy is to remove the plants until the hotbed has been remade, with the addition of some materials the fermentation of which is slower and less violent. Gardeners sometimes attempt to avoid the trouble of doing this by piercing the sides of the hotbed with holes for the egress of heat; but this is seldom an effectual remedy for the evil.

HOTCHPOT. (Law.) The word has been thus quaintly explained by Littleton:—"It seemeth that this word hotchpot is in English a pudding, for in a pudding is not commonly put one thing alone, but one thing with other things together." The common law prescribed the rule, that where a daughter to whom lands had been given in frank marriage claimed a portion of the lands descending upon her together with her sisters from the father in fee simple, she should not take any share unless she mixed and blended the lands given to her in frank marriage with the descended estate, so that they might be equally divided among all the daughters. The rule is founded upon the same grounds as the Collatio bonorum of the civil law. ('Dig.' xxxvii. 6; 'De Collationibus.') The statute 22 and 23 Chas. II., c. 10, s. 5 (the Statute of Distribution) provides, that in making distribution of the personal estate of intestates, advancements made by them in their lives to their children shall be brought into hotchpot.

HOTHOUSE, in horticulture, is a structure in which exotic plants are cultivated under circumstances approximating as closely as possible to those under which they naturally exist; or it is used for accelerating the production of flowers and fruits of either indigenous or exotic plants. Hothouses appropriated to the latter purposes are very frequently termed *forcing-houses*.

In the beginning of the 17th century that description of hothouse generally termed the *greenhouse* began to be constructed in Germany; and one in the Apothecaries' Garden at Chelsea is mentioned by Ray in 1684. These, like many others of later construction, had glass only in the front, which was perpendicular; and the mode of applying artificial heat exhibited little more knowledge of means for the end than the remains of flues found in the ruins of the dwelling-houses and baths of the Romans.

In 1724, when Switzer published his treatise entitled 'The Practical Fruit Gardener,' the principles of managing hothouses were still very imperfectly understood; for he observes, p. 305, that "Peaches, nectarines, and apricots don't love to be forc'd; at least the fruit is very seldom good: there being much occasion to keep the glasses close, the fruit is always rendered flat and insipid. This is not pure speculation, but the result of the practice that I have observed in the glass houses at Brompton Park."

Considerable alterations, particularly in houses for grapes, were made towards the end of the last century. The most material improvement was the substitution of a slanting glass roof for a perpendicular glass front; but the advantages of this were much diminished by the heaviness of the sashes, and the large quantity of opaque matter which it was thought necessary to employ in order to ensure the durability of such structures.

In the present century great advances have been made in hothouse building, and more particularly since 1815. The application of heat by steam or hot water, and the admission of a greater quantity of light by glazing on metallic bars instead of wooden sashes, are the principal features of these improvements.

The principles by which the construction of hothouses must be governed have reference to the three great agents in vegetation—*heat*, *moisture*, and *light*.

With regard to *heat*, the building must provide for a sufficient amount to raise the internal temperature of the house, from that of the lowest degree of external air that occurs in this climate, to that of the highest which prevails for any length of time in the countries of which the plants intended to be introduced are natives. This rule is without exception as far as plants strictly tropical are concerned; a slight relaxation may be allowed in some cases with regard to plants of temperate climates, such as, for instance, the vine when it is only intended to be forced late in the season, after the severity of the winter is over. With regard, however, to vineries intended for early forcing, the extremes of temperature should always be made the data for calculating the extent of the requisite heating power. The consequences of too limited a heating power will, in many instances, be exhibited for several years. Vines in a forcing state have been so affected by the extreme cold of a single night, that the crop has been not only lost, but the vines themselves so much injured as not to be worth preservation. This shows the necessity of always providing for extreme cases, since a deficiency of heat for only a few hours may occasion an injury that cannot be remedied in as many years.

Moisture is of very great importance, and a due proportion of it is frequently more difficult to maintain in the atmosphere of the house than heat, and more so by some modes of heating than by others. It therefore follows, that as all applications of fire-heat have a tendency to produce too great a degree of dryness, that mode is the best for the growth of plants which allows of the greatest quantity of vapour to remain uncondensed in the atmosphere of the house.

Some tribes of exotic plants, natives of the torrid zone, are adapted for existing under a very dry atmosphere. Instead of developing a thin expanded foliage, they form thick succulent masses, which no degree of atmospheric dryness seems to injure. Plants of such a nature of course require a *dry stove*; and a period of extreme dryness is perhaps as necessary for their future vigorous development as the cold of winter is to the deciduous trees of the north. But with regard to the generality of plants from tropical regions, a very different atmosphere is necessary. Within the tropics, the dryness of the air seldom exceeds 10° of Daniell's hygrometer; whereas, in the neighbourhood of London, between 20° and 30° are frequently indicated during the day. In tropical countries the air is saturated with moisture during the night, or at least it is but very rarely otherwise in the open air. But if due precautions be not taken and temperature only be attended to without regard to moisture, a degree of dryness will prevail at *night* in hothouses, which is double that of the tropic during the *day*. Artificial heat having therefore this excessive desiccating tendency, the necessity becomes obvious of adopting such modes of construction and heating as will afford the best means not only of supplying but of maintaining moisture; for vapour may be raised till the air of the house is at the point of saturation, and yet causes may operate so as to occasion a speedy condensation and a consequent dryness.

Light cannot be admitted too freely into hothouses. This will appear evident from the circumstance of the most transparent medium that can be used reflecting a great proportion of the sun's rays when they impinge obliquely on its surface. According to Bouguer's 'Table of Rays reflected from Glass,' when the angle of incidence is 85°, as much as 54 per cent. of the sun's rays are reflected; and at angles of incidence of

80°,	70°,	60°,	50°,	40°,	30°,	20°,	10°,	1°
41,	22,	11,	6,	3,	2,	2,	2,	2

per cent. are reflected, omitting fractions.

Besides this, in wooden roofs, even although of good construction, 22 per cent. of the rays of light are obstructed by the rafters, &c. In iron roofs the obstruction is reduced to 7 or 8 per cent. In the case of a house fronting due south, the rays of the sun at 6 A.M. will run parallel with the roof; at 7 A.M. 30 per cent. of the rays will be reflected from the glass alone, independent of the quantity from other causes. At 8 A.M. 10, and at 9 A.M. about 4 per cent. will be reflected. From this time till 3 P.M. the proportion reflected will be only from 2 to 4 per cent. If we therefore take from 6 A.M. to 6 P.M., a length of time from which the tropical days never differ much, we may calculate the loss of rays to be from

Reflection of glass, say on an average . .	10 per cent.
Obstruction from rafters (iron) . .	8 „
Ditto from glazing laps	5 „
	23 per cent.

But if wooden rafters are employed, 15 per cent. additional must be added, making in this case a loss of 38 per cent. In old and heavily constructed houses, it certainly would not be too much to state the loss of rays at 50 per cent.; and under this privation of light it is not surprising if the plants are found to exhibit a yellow sickly foliage.

The above calculation of the reflection of rays is made on the supposition that the *pitch* or elevation of the roof forms an angle with the horizon corresponding with the latitude of the place, say for London 51½°, or forming an angle with the back wall equal to the complement of the latitude, or 38½°. The period of the season is that of the spring or autumn equinox. A plane elevated to the above angle would have the sun's meridian rays more nearly perpendicular throughout the year than could be the case with any other elevation. This however is not the most eligible angle of elevation, except perhaps in the case of a very early forcing vinery or peach-house, where the direct rays of the sun are more especially required at an early period of the season. The principal objection to this elevation is, that it occasions the house to be built too high in proportion to its width, and the heat accumulates in the upper angle where it is least wanted; in short, the higher the back wall, the colder is the air of the house at its base, and the warmer at the top, compared with the mean temperature throughout the house. It will therefore be proper to inquire how far the above elevation may be deviated from without greatly affecting the transmission of light. If the slope of the roof were lowered so as to form an angle of 20° with the horizon, the loss from reflected rays at noon would average about 3 per cent.; but in the morning and afternoon the loss would be considerably greater, more especially in the winter season; and it is of course proportionally less in summer. So far therefore as light is concerned, any angle may be chosen that is found in other respects the most convenient between 20° and 50°. Pine pits and frames are even lower than 20°; but with reference to the supply of light, as well as the descent of the rain, it is not advisable to have the roof flatter than 20°.

Although the necessity of admitting as much light as possible is now generally acknowledged, and although in cloudy weather great advantage will be derived from a roof rendered as transparent as possible, yet the generality of tropical plants do not thrive in bright sunny weather when placed near the glass of a hothouse in this climate; and the necessity of a screen of netting will appear obvious from the effects of solar radiation observed in the tropics as compared with, what is rather surprising, the still greater energy of the same in this country. In the tropics, a thermometer covered with black wool, and consequently prepared to receive the full effects of the sun's rays, does not rise higher than one so exposed in this climate frequently does, notwithstanding the greater general coldness of the air. It is not uncommon in the neighbourhood of London for a thermometer placed in the sun to rise 50° Fahr. above one in the shade. At Cumana, Humboldt never found the sun's rays to have the effect of raising the thermometer more than 6° or 7°. Nearer the pole, the energy of the solar rays appears to be still greater than in this climate. Between lat. 80° and 81°, Captain Scoresby states that the thermometer was 18° below freezing on one side of the ship, whilst on the other the pitch was heated to a temperature of 90° or 100°. This is a greater radiating effect than has perhaps ever been observed in this climate, and certainly unequalled in the tropics. The body of the atmosphere surrounding the earth is supposed to have the form of an oblate spheroid, flattened at the poles and elevated at the equator. Indeed if this were not the case, as it is found to be considerably denser at the poles than at the equator, a different barometrical indication would be the consequence; but at the level of the sea this is everywhere the same. This difference in density may have some effect in weakening the sun's rays, but probably not so much as the circumstance of the atmosphere having a much greater capacity for moisture at the equator than at the poles. At the equator more moisture is required to produce saturation, and at the same time the process of evaporation is so powerful that the atmosphere is maintained on an average much nearer the point of saturation than it is at the poles. These circumstances doubtless contribute greatly to temper the solar rays.

Plants from a great elevation, from within the tropics as well as elsewhere, appear to require less shade than those from the level of the sea. The rays of the sun have been ascertained to be more powerful at 4000 feet above the level of the sea on the mountains of Jamaica than at Port Royal. Hence the potatoe, a native of the high tableland of South America, will not thrive under glass unless placed very near it; and if placed at a distance from it at which the pine-apple, a native of the same country, but near the shore, will grow robust, the potatoe will become pale and languid.

These facts are too important to be omitted in explaining the principles by which the construction of hothouses ought to be regulated, and it will be found that those houses are the most perfectly suited to the cultivation of plants in which such principles have been most considered.

With regard to the means of supplying artificial heat, the old system of using brick flues is now rapidly being superseded by that of hot water. Brick flues occupy a large space; and are also liable to crack and emit sulphureous effluvia to such an extent that the crops of early forcing fruits have often been entirely destroyed. These objections do not apply to hot-water pipes. When once fitted up they require no repairs for many years; whereas the brick flues must be frequently broken up in order to clear out the soot. By hot water the distribution of heat can also be better regulated, and the uniformity of temperature better maintained than by any other known means. The methods of heating by hot water are various. The oldest and perhaps the best for small houses is extremely simple, consisting of a boiler, and, at the further end of the house, a cistern on a level with the boiler. A pipe proceeding from near the top of the boiler, and communicating with the cistern at the same level, conveys the heated water slowly from the former to the latter. Another pipe, situated lower than the preceding, conducts the colder and consequently denser portion of the water from the cistern to the boiler. This is frequently called the return-pipe. A circulation is thus established in consequence of the hottest and therefore the lightest portion of the water ascending, and displacing the colder in the upper pipe, which from its greater density tends to subside at the lowest level, which is in the lower or return pipe. Here it would remain stationary, but the pipe communicating with the water in the boiler, a few inches above the bottom of the latter, and the rarefied water in the boiler being unequal to the balancing of the colder and consequently denser portion in the return-pipe, a continual ingress from the latter takes place into the boiler.

This extremely simple form of the hot-water system has received various modifications. Circulation has been obtained on the siphon principle, the pipes being elevated above the level of the boiler, and a vacuum being formed in them by pumping out or otherwise displacing the air, which is replaced by the water, so that a greater descent is afforded for the water in the return-pipe. Instead of large pipes, of about four inches in diameter, a number of small pipes hermetically closed have also been employed, and coils of such pipes have been inclosed in a furnace instead of a boiler; a large extent of radiating surface is thus made to inclose a comparatively small quantity of water. As the water becomes heated, a degree of pressure corresponding with its expansion takes place; this, however, requires to be regulated by an expansion-tube to prevent explosion. Steam forced through pipes has also been extensively used as a heating agent. Such modes undoubtedly afford the means of raising the temperature more rapidly, and their application in some cases may be attended with advantage; but as the cooling, if the fuel be not supplied regularly, takes place in the same ratio of rapidity, it becomes a question whether a mode that produces a slow and lasting heat, or one that is rapid in its production and decline, is to be preferred. In order to solve this, it becomes necessary to take into consideration the progressive amount of heat which is required in hothouses relative to time. At noon, or soon after, the natural temperature of this climate is generally at the highest, and the temperature of the hothouse should also then be higher than at any other time of the day or night. The external temperature declines gradually till three or four A.M., when it reaches its minimum, of perhaps 50° below the noon temperature. The hothouse temperature should in like manner gradually decline, but only to the extent of between 5° and 10°. It is therefore evident that artificial heat must be increased, if well applied, so as exactly to make up the deficiency; and it should by no means be allowed to have any more than one rise and fall in the course of twenty-four hours. By a rapidly heating apparatus, this is next to impossible; and independently of all other inconveniences, sudden changes of temperature are sure to affect the hygrometrical state of the air in the house, causing condensation and consequent dryness. A slow but effective and lasting heating power is therefore preferable.

Only a very few modifications of the plan of heating by hot water require to be adverted to in this place. Instead of the pipes running quite horizontally from the boiler to the cistern, they may be slightly elevated towards the latter, which has the effect of conveying a greater proportion of the heat to the part of the house which is most remote from the boiler. The boiler must be so constructed and placed as to admit of the water contained in it being a little higher than the most elevated portion of the upper pipe. Flat pipes are sometimes employed as upper ones. As their transverse section is a parallelogram, and as a circle contains more space than any other figure of equal perimeter, these flat pipes contain less water in proportion to their surface, and consequently the water in them is sooner heated to its maximum; but this, as previously shown, is no advantage, if in fact it be not a disadvantage, since it cools so much sooner.

With regard to a supply of moisture, the above hot-water system, in which the pipes are level, or nearly so, presents several advantages over other methods of heating. Troughs can be arranged along the whole length of the pipe, which, when filled with water, will produce a gentle but constant evaporation. Besides the supply from this source, a large quantity of steam may be safely introduced from the boiler, provided the violence of its ingress be a little broken by a perforated sheet of metal, or any similar contrivance. Another source of moisture is supplied by the reservoir, which, with moisture from the soil in which the plants are grown, and from the wetted floors, ought to keep the atmosphere of the house sufficiently moist during the night. The elasticity, however, of the vapour will be very great, particularly in cold nights when much fire heat is required; and in such a state of the weather the condensation from the coldness of the glass will be increased. The atmosphere of the house is not only deprived of its moisture by this process, but a serious loss of heat by radiation from the glass takes place at the same time. This loss of heat and transmutation of moisture resulting from the radiation of the glass, although little attended to, demands the most serious care. It admits of no remedy but the interposition of some medium between the glass and cold sky; and such substances as are the worst conductors of caloric, and which will also keep the glass dry, are of course the best. A woollen net mounted on a roller, with pulleys attached, would have a very beneficial effect if closely covered by light wooden shutters or a tarpaulin. And as it has been proved that the rays of the sun are frequently too powerful for hothouse vegetation, the netting would likewise be occasionally very useful as a shade; and with this provision the roof cannot be made too transparent, as previously stated.

It has been shown that iron roofs occasion an obstruction of light to the extent of only one-third of that which takes place when wood is employed. The iron roofs are therefore preferable, although, apart from the greater original expense, there are still some objections to them. Formerly the chief objection was the breakage of glass likely to result from the expansion of the metal; but the severity of the frost in 1838 has proved that this objection was groundless, for very little breakage occurred in the iron roofs compared with what took place in wooden ones; and it may be fairly asserted that none whatever was broken from contraction of the metal; nor can any breakage take place from its expansion if the glazing is performed in summer, or the glass cut so as to fit in with ease, or the panes made one-thousandth part of an inch less than the bed between the rebates of the bars in which they are placed. The principal remaining objection is that of the rapid abduction of heat. Plants never do thrive so well in the proximity of iron as in that of wood, and this is probably owing to the wood being a slower conductor of caloric. Supposing a bar of iron is heated to 100° by the sun's rays, and then syringed with water, it will instantly become very cold, in consequence of evaporation; and if any plant be in contact with it, or nearly so, the juices will experience a chill. In many instances, therefore, where plants require to be close to the glass, such as in propagating houses and pits, wood is certainly preferable to iron. Again, when a wide and also lofty house is to be glazed, iron is more proper; for besides the quantity of rays lost by reflection of glass and obstruction from rafters, those that do pass into the interior are so weakened, that when they reach vegetation remote from the glass they do not appear to be effective in performing the requisite functions in a perfect manner; but of course better when the roof is of iron than when wood is employed.

Various modes of ventilation are in use. One which was considered a great improvement has not been found to be so,—namely, the having ventilators in front at the lower angle, and corresponding ones in the back wall near the top inside, communicating with the external air by means of openings in the south side of the parapet. Sometimes this mode appears to have little effect, and the temperature ascends too high, till the movement of a slight breeze outside causes instantly a rush of cold air. Ventilation should be so contrived as to be sufficiently effective in preventing excess of heat; but at the same time it should be perfectly at command, so that it may be employed when requisite in the most limited degree. No method should be finally adopted until it is put to the test by trying whether, under any agitation of the external air, a candle will burn steadily inside if placed near the apertures by which the air is admitted.

In all forcing-houses tanks should be placed for supplying water of a temperature more suitable to the nature of the vegetation than that from a pump out of doors. Nothing can be more injurious than cold water applied to the roots and tops of tropical plants, or others in a forcing state under a high temperature. The rain and dews which supply the plants of warm climates cannot be much below the mean temperature of the climate; and if only equal to the minimum, still it would be between 20° and 30° above that of spring-water in Britain.

To these general remarks upon the principles of constructing hothouses, a few observations of detail require to be added. Greenhouses and conservatories are commonly included in the appellation of hothouse. The only difference between them is, that fires are seldom used in the greenhouse unless in very severe weather, while the hothouse is constantly kept at a high temperature; but so far as the building is concerned, they may be considered as the same. A greenhouse is for keeping and growing the plants of temperate countries; while a hothouse is used for forcing fruits, or for growing plants which are indigenous to tropical regions. Hothouses may be classed under four different heads,—namely, the *dry stove*, the *damp stove*, the *bark stove*, and the *forcing-house*.

The *dry stove*, as the name implies, is used for the cultivation of plants which do not require much water; such as the different species of Cacti, some Euphorbias, and other Succulents of like habits. The management of such a house is very simple. The temperature during the winter months should never exceed 55° of Fahr. No water should ever be given at that period, unless the plants show signs of suffering from want of it; indeed very little water should be given at any season, except when the plants are growing. In spring, or early in summer, most of the plants will show an inclination for growth, and then they may be watered about twice a week, but this must be done with great caution, otherwise they are very apt to rot. During summer fires may be discontinued, and plenty of air given in fine weather. The plants will probably get covered with dust and will be unsightly; in this case they may be syringed, but caution must be used in doing this, especially with melon-shaped Cacti, as the water lodges in their hollow tops, and eventually destroys them, if allowed to remain.

The *damp stove* requires treatment of an opposite description. Instead of being kept dry like the last, its atmosphere should be always excessively humid, except in the winter season, when the sky is generally cloudy, and the sun's rays weak. Various methods are adopted to keep the atmosphere in this saturated state. When the house is heated with common smoke flues, the most simple way is to throw water frequently upon them, and also upon the passages and other places, from which it will evaporate, and surround the plants with a moist atmosphere. Sometimes a channel is formed with cement, upon the upper surface of the flue, which keeps the water from running off. This is a very excellent plan, as it may be so made that it will hold a considerable quantity of water, which will be continually evaporating, and serve the same purpose as that of a person frequently throwing water upon it. When the house is heated with hot-water or steam-pipes, it is a good plan to get small ridges cast upon the sides of the pipes, if they are flat, or, if they are round, small cisterns made of lead or zinc will answer the purpose, which can be used in the same manner, and will have the same effect as the channel upon the smoke flue. With the exception of a few months in winter, the damp stove must be regularly syringed twice every day. This is indispensable to the health and vigorous growth of the plants, and also necessary in order to keep down insects. The quantity of water which the plants in this house will require depends entirely upon the state of the weather and their own growth; in winter they will need little, as spring advances they may be watered more freely, and in the summer season they will all require to be watered twice and some of them three times a-day; of course those which are growing vigorously will require the most. It is a very bad plan, although one which is too often practised, to water almost at random, giving all the plants almost an equal share, regardless of their different capacities. Some will require a very abundant and constant supply, others will almost live upon the atmospheric moisture that surrounds them. Another thing to be attended to in the treatment of this stove is the placing of the plants. Most of the kinds grow very freely, and if they have not plenty of room they will very soon get crowded, and instead of growing bushy and handsome, the result will be an unsightly specimen, with a long bare stem and a few leaves upon its top. To prevent this they must be regularly looked over, tied up, and kept clear of each other; elevating some, depressing others, and giving the whole not only enough of room but also a natural appearance. The temperature of this stove, like that of the dry-stove, should not be the same at all seasons; in winter, when the plants are in a torpid state, 55° or 60° of Fahr. is quite warm enough; when vegetation begins to take place, as spring advances, it may then be gradually raised to 70°; and during fine weather, in the middle of summer, fires may be discontinued for about three months; but this must depend entirely upon the weather. The thermometer should never be allowed to sink lower than 60°.

The *bark stove*, when it is of large dimensions, consists of a pit in the middle of the house, surrounded by a brick wall, leaving as much room round the sides as will form a passage to walk in. This pit is generally from four to six feet in depth, one-half below and the other half above the level of the floor of the house; but this depends chiefly upon the height of the roof and the object in view. In smaller houses no space is left for a passage, and the inside is entirely occupied by the pit. The pit is filled with bark (commonly called tan, from its having been used previously by the tanners), and after being allowed to sink a little and ferment, the pots containing the plants are plunged more or less deep as prudence may suggest. It is dangerous to plunge the pots too deep at first, before the heat of the bed is fully ascertained, because in that case the roots are very liable to be burned; the better way is to plunge the pots only about one-third at first, and deeper afterwards. Sometimes leaves are mixed with the tan; the reason being that they are in some parts of the country more easily procured. When the heat begins to decay, the bed must be turned over and a little fresh tan added; and whenever a new bed is made, a little of the old tan should always be mixed with the new. This stove is heated independently of the bark, of which the principal use is to warm the roots of the plants. A bark bed is found useful in the cultivation of all those kinds of plants which are grown in the damp stove; orchidaceous plants, for example, succeed admirably in this way. The treatment of it, so far as the temperature, watering, and syringing are concerned, is precisely the same as is recommended for the damp stove.

What are called *Palm-houses*, *Musa-houses*, *Orchidaceous-houses*, &c., are merely damp stoves of different dimensions, for the cultivation of those different subjects.

The only other hothouse distinct from those already noticed is the forcing-house. The treatment which this requires is essentially different from any which has been described, the object being not merely to grow the plants, or to make them produce flowers, but to obtain fruit, and that too at particular seasons. [FORCING.]

Hothouse plants are peculiarly liable to the attacks of insects, and unless carefully and constantly attended to, these little depredators do a vast deal of mischief. The most common kinds are the *Green-fly*, *Thrips*, *Red-spider*, *Brown-scale*, and *Mealy-bug*. The first of these is easily conquered by fumigating the house with tobacco, or syringing the plants with an infusion of the same substance. The best remedy for the thrips and red-spider is to syringe well, and keep the house very moist and warm, as those insects cannot live in excessive moisture; a little of the flowers of sulphur shaken upon the leaves will also destroy them. The brown-scale and mealy-bug are the worst of all that infest plants in hothouses. Bruised laurel leaves strewed upon the passages and other parts of the house are said to destroy them, but these must be used with great caution, as they may not only kill the insects, but the plants themselves. Various other substances are said to destroy them, but, after all, the best and surest remedy is to wash them off. This is perhaps rather difficult where these little intruders are numerous, but after the plants are once clean, it is an easy matter with a little attention and diligence, to keep them so.

HOT-WALL. Hot or flued walls are constructed in cold countries, for the purpose of affording warmth to trees placed against them, so as to counteract the effects of frost in autumn, when the wood and buds are maturing, and in spring, when the blossoms and leaves are unfolding. If hot-walls are used for these purposes only, they are productive of great benefit to the plants which they shelter; but if, as often happens, in addition to this it is attempted by their aid to advance the ripening of fruit in any considerable degree, hot-walls are of very doubtful service. This uncertainty of success arises from the exposed condition of the surface of the wall, and the consequent liability of the heat to be dispersed as rapidly as it is generated, either in consequence of wet causing evaporation, by which the bricks themselves are cooled, or by cold sweeping winds, which prevent any accumulation of warm air from being formed. In mild weather, a hot-wall with a south aspect will forward vegetation very considerably; but in proportion to the extraordinary excitement, so will be the check from subsequent chilling blasts which this variable climate is so subject to in the early part of the season. Besides the dissipation of heat on the south side an equal, if not a greater portion, is radiated from the north side of the wall, where it may be said to be entirely lost. It is therefore evident that wherever coals are expensive, hot-walls are not to be recommended, except for the sole purpose of rendering a little assistance towards ripening the wood in autumn, and warding off the effects of frosty nights in spring.

One furnace is allowed for heating about 40 feet of wall, that is, 20 feet on each side of the place where the fire is situated. The flues on either side are made to take four courses, or two returns; the first course being a little above the surface of the ground, and the upper 1½ or 2 feet below the coping. An improvement consists in admitting, by means of a register, a portion of the heat directly from the furnace into the second course of flues. A thick double woollen netting ought to be provided for the protection of the plants on the wall, and so attached to rollers as to be easily rolled up in fine weather, and let down at night. This, with a close-fitting wooden coping, projecting at least 12 inches, will, in a great measure, obstruct the radiation of heat. By such means very excellent crops of cherries have been obtained at an early period of the season; and as this species of fruit is precarious to force in a hothouse, a portion of a hot-wall where the trees are planted permanently may be very properly set apart for such an object.

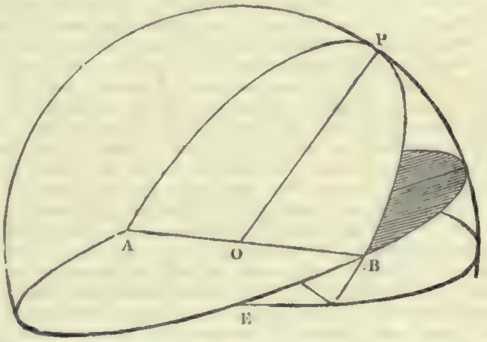
Instead of flues, hot-water pipes might be introduced into the cavity of a common hollow wall, a little above the level of the border. One range of 4-inch pipe would be sufficient for at least 200 feet of wall, the boiler being placed at the back of the wall, and having an upper and lower pipe extending 100 feet each way. If, as sometimes happens, a glass case is erected in front of a hot-wall, a hot-water pipe should be made to pass along in front of the trees, about two feet from the wall, and the return-pipe only might be placed in the cavity of the wall. A great saving of fuel would be the consequence of such an arrangement.

HOUR, HOUR-CIRCLE, HOUR-LINE. The first word always means the twenty-fourth part of a day, by what revolution soever the day may be measured. [TIME.] In angular measure [ANGLE] it signifies the twenty-fourth part of a complete revolution, or 15°.

Any great circle on the sphere which passes through the two poles is called an hour-circle, because the hour of the day is known when that circle of the kind mentioned is ascertained upon which the sun is for the time being. But the two semicircles into which the poles divide such a circle belong to different hours, and are twelve hours asunder. In fact, it is a *semi*-circle which is spoken of under the term hour-circle. [SPHERE, DOCTRINE OF.]

The hour-lines of a sun-dial are the lines on which the shadow falls at different hours, and are the intersections of the hour-circles with the plane of the sun-dial. In the times preceding the common use of clocks, the science of dialling was of considerable importance, and many works were written on the subject, in which the forms of such instruments were varied without end, and also the methods of constructing them. One work even announces "a new conceit of reflecting the sunne beames upon a diall, contrived on a plane which the direct beames can never shine upon." In the rest of this article we propose to show how to construct any plane sun-dial, or rather how to calculate the hour-lines for it by means of spherical trigonometry. A maker of sun-dials should form a table for every species of dial which he wishes to construct, once for all.

Firstly, suppose the dial to be perpendicular to the meridian, which is the case in the horizontal sun-dial and in the vertical south sun-dial. In this case the line drawn through the dial, in a vertical east and west plane, must be horizontal. The style of the sun-dial is of course to point towards one of the poles. Let O be the centre of the globe, and of SEN the circle on which the dial is to be drawn, and let SPN be the meridian, P being the north pole. Then at noon the shadow of the style (a portion of the line OP) is on ON. Let the position of the sun in the afternoon be in the plane of the hour-circle APB, and let the real solar time be h (hours or minutes), and turn h into degrees, &c., at the rate of 15° to an hour of time. Let H be the angle thus obtained. Let a be the angle by which the plane of the dial is to dip below the horizontal plane, and l the latitude of the place. Then in the right-angled spherical triangle PNB, the side PN or PC − NC is $l - a$. and the angle BPN (=SPA) is H. But NB (answering to the angle NOB) is the angle made by OB, the hour-line wanted, with ON, the noon hour-line: let it be called H′. And by the properties of right-angled spherical triangles,



$$\tan H' = \tan H \times \sin (l - a);$$

from which H′ may be calculated for as many values of H as may be necessary. If the dial be horizontal (the most common case) we have ($a = 0$)

$$\tan H' = \tan H \sin l;$$

and if the *north* side of the dial dip instead of the south, by an angle a, the formula is

$$\tan H' = \tan H \sin (l + a).$$

In the case of a vertical south sun-dial, in which the style must point towards the south pole, we have

$$\tan H' = \tan H \times \cos l.$$

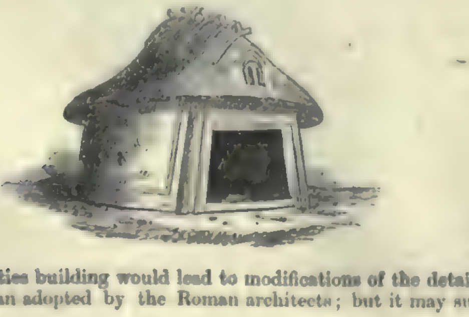
Secondly, suppose the dial to be not perpendicular to the meridian. In that case the circle SPN, perpendicular to the dial, is not the meridian, and it must be ascertained what angle it makes with the meridian, and thence, what hour-line is ON. This being found, the dial is constructed in the same manner as before, and the hour-lines follow the same law, with this exception, that the preceding formula does not measure the angles from the twelve o'clock hour-line, but from some other. It is not worth while to pursue this case further.

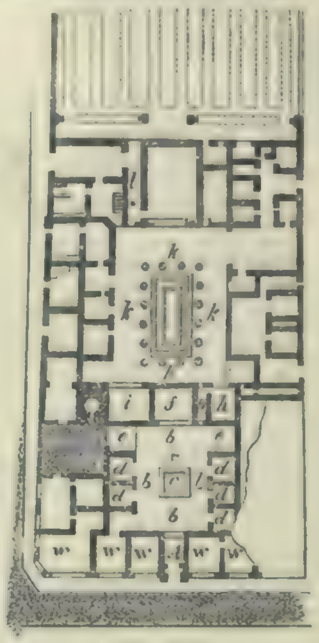
HOUSE. The buildings erected for the habitation of well-to-do private citizens, and occasionally those intended to shelter animals, or to receive particular descriptions of machinery, are generically known by the name of *houses*, in contradistinction to *palaces* and *mansions* (or the habitations of rulers in the land), and to *huts*, or *hovels*, and *caverns*, in which the very poor or the uncivilised seek protection from the inclemencies of the atmosphere. As the construction of houses must depend upon the local conditions of climate, of the materials used, and of the state of civilisation which prevails at the period of their erection, it follows that the varieties of house construction must be infinite; and it will, therefore, be advisable to limit the observations to be made on the subject to the practice which has prevailed in the most distinctly marked countries, or periods, of ancient or of modern times, in this branch of architecture.

It appears, from Sir G. Wilkinson's 'Manners and Customs of the Ancient Egyptians,' that the houses of that country, and very probably those of all the earlier nations of the East, were erected upon nearly the same plans as were subsequently followed by the Greeks and Romans, in the cases at least of the town residences of the wealthy citizens. They were usually composed of a forecourt, separated from the street by a wall, and containing a few trees, a tank, or a fountain in the centre. Doors opened from this court into a reception room, wherein the master of the house received strangers, and into passages leading on the right and the left to the dwelling rooms or the offices. In some instances it would appear that there were two, or even three, stories; but as a general rule the Egyptian houses consisted only of a ground floor, with a few rooms of inconsiderable size, and more like summer houses than dwelling apartments, upon the level of the terrace which usually covered the building. The doors and windows were closed with wood panels on hinges; the walls were constructed of crude unburnt bricks, and they were carefully stuccoed with the mouldings, pilasters, and cornices of the door dressings, executed in that material and painted to look like stone; the floors were either of stone or of a species of mortar, and the roofs were made of wood beams covered with planks, or occasionally of brick, or even of stone, vaulting. In the houses of two or more stories, the rooms upon the ground floor were used as store rooms, and those upon the upper floors were used as bed rooms or as living rooms.

The houses of Athens of the time of the republic are described as having consisted of a forecourt, or a portico, at the bottom of which was the entrance to the dwelling rooms, and these were divided into two compartments or stories, the lower one for the men, the upper one for the women. In the houses erected in Greece at the period of the Roman dominion, however, the distribution seems to have been more complicated; and, from the researches of Sir W. Gell, it may be inferred that the plan then adopted was nearly as follows:—A court surrounded by a peristyle was entered, either directly from the street, or through a passage between the stables or offices. From this court access was obtained through the Prostas to the Thalamus or Antithalamus, where the women worked, and to the Oicos, or the great dining room, around which were arranged the *hospitalia*, or strangers' rooms. The sleeping apartments of the women were on the upper floor, and they were approached by a staircase, in such a manner as to separate the *gyneconitis* effectually from the rest of the house when required. Even to a very recent period of the Grecian history the houses seem to have been constructed entirely of wood, with the exception of the roof covering of tiles; for it is to be observed, that the Oriental system of terminating the houses by a terrace was not habitually adopted in Greece, where the atmosphere was more exposed to sudden variations, and was at all times less dry than that of Asia Minor or of Africa.

When Rome had rendered herself mistress of the ancient world, and her citizens began to indulge the monstrous luxury which characterised the later days of the Roman civilisation, the style of house-building participated in the changes introduced in the manners and customs of the nation. There are no remains of the private residences of the Romans of the period anterior to the close of the third Punic war; but, from passages in Pliny and Vitruvius, it would appear that they were constructed in a very simple manner, and of rude and perishable materials. The walls were built of unburnt bricks, and were only of one story in height; the roofs were of wood, and covered with reeds or thatch; and, as might have been expected under such circumstances, whenever a fire did occur, the destruction of whole quarters of the town necessarily followed. During the later days of the republic, and, in fact, so long as the Roman empire lasted, the style of house construction, for the purposes of the wealthy portions of that strange society, was affected by the awful excess of luxury amongst the higher classes attendant upon the social organisation of the heathen world; and we consequently find that the residences of the rich were built with every imaginable refinement, while those of the poor continued to be as rude and as perishable as they were in the earlier periods of Roman history. In the first part of Mazois' 'Ruines de Pompéi,' Paris, 1824, folio, the reader will find an elaborate treatise on the habitations of the ancient Romans, with some interesting plans of houses, copied either from the relics of the most perfect remains still to be found in Italy, or from the sculptured plan of Rome, executed in the time of Septimus Severus, now existing in the Vatican; and he also gives a sketch of the original Latin dwelling, of which a reduced copy is appended by way of contrast. Of course the circumstances of the respective parties building would lead to modifications of the details of the normal plan adopted by the Roman architects; but it may suffice to observe that, wherever it was possible so to do, the various parts enumerated upon the subjoined plan were introduced, and the house of Pansa, discovered in the ruins of Pompeii, may fairly be taken as the type of the domestic architecture of the masters of the ancient world, in one of the favourite Italian provinces at least.





In this plan, the entrance from the street takes place through the *prothyrum* (A), where the porter was stationed, and which served as a passage between the shops (w w) immediately facing the street, and connected or not with the main building, as might be desired. From the prothyrum the clients, or visitors, of the proprietors passed at once into the *cavædium*, or Tuscan Atrium, surrounded by covered galleries (*b*), but having an open space in the centre (*c*), and upon the floor a basin or tank to receive the rain-water from the roofs of the galleries. [ATRIUM.] Around the cavædium were the apartments of the domestics (*d*), and some small reception rooms (*e*) for business visitors; and immediately opposite to the prothyrum were, firstly (*f*), the *tablinum*, or summer dining room, separated from the cavædium by a curtain; secondly, the (*g*) *fauces*, or passage leading to the inner apartments; and thirdly, the *cubiculum* (*h*), or bed chamber, and perhaps the *pinacotheca* (*i*), or picture gallery: the entrance to both the latter apartments was, however, from the inner court or peristyle. This *peristyle* (*k*) consisted of a large court surrounded by columns supporting a covered gallery, from which access was given to a series of apartments occupied by the members of the family, to the store closets, to the shrine of the household gods, and to the *triclinia*, or private dining rooms. There was, at the rear of Pansa's house, a garden, approached through *fauces* (*l*) on the end wall; and it would also seem that there was a series of apartments detached from the rest of the house, together with a number of shops, entered from the side streets. The shops, if we may judge from the remains of the staircases, contained two stories; but the main building was entirely upon the same level throughout. The materials employed were of the most costly description, and painting, sculpture, mosaic, marbles, inlaid woods, &c, were used with unbounded prodigality; and every precaution was observed for the purpose of regulating the uniformity of temperature in the apartments especially devoted to the uses of the family. In short, the general system of the Roman houses may be described as having consisted in the construction of separate blocks, or *insulæ*, containing one large *villa*, and a series of small shops occupied by the tenants of the principal proprietor; and the villa itself was divided into two distinct parts, one of which was devoted to the public or official duties of the proprietor, and the other to his family requirements.

During the stormy period of transition from the ancient to the modern social organisation, the traditions of Roman art continued to prevail in Europe, and the houses of the kings, and of the monastic institutions of the middle ages, were designed upon nearly the same principles as those of the Roman villas. The porch, the forecourt, the parlours, the refectories, the cloisters, and the sleeping apartments immediately around the latter, were evidently placed in imitation of the analogous parts of the Roman villas; nor was it until the abuses of the feudal system had driven the inhabitants of towns to enter into a combination for mutual defence, capable of securing the freedom of the towns, that anything like domestic architecture displayed itself. As might naturally have been expected, the first indications of this Art in the more modern times were to be traced among the Latin nations of the south of Europe; for in them the municipal life of the

Romans had passed more thoroughly into the spirit of the nation than it had done in the north; and we accordingly find that the earliest specimens of mediæval house-architecture are to be met with in Italy, Spain, or in the south of France. Some of the earliest, and the best, specimens of this phase of art are to be found in the town of Cluny, in the Department of the Soane et Loire, and in Florence, Pisa, &c. in northern Italy, where the houses though built in a sufficiently solid manner to enable their proprietors to resist a sudden attack, were evidently more adapted to the requirements of the civil life of modern societies than the immense dwellings of the ancient Romans could, by any possibility, have been made. In proportion as the middle classes rose into power and influence, the domestic architecture of Europe also assumed importance; and indeed it may be received as a general law that house building, in the meaning we usually apply to the word, owes its origin in a secondary sense, to the development of the municipal institutions which brought those classes into power at the dawn of modern civilisation. About the 12th and 13th centuries Venice, the Hanse towns, and the numerous cities of Flanders attained the apogee of their glory; and the numerous beautiful houses of that period may still be referred to with admiration, though of course the improvements in the means and appliances of domestic life have rendered the domestic architecture of this particular period inapplicable at the present day. The primary law of the development of domestic architecture will be alluded to in the sequel.

In fact, we may observe, the defective state of the municipal organisation of the middle ages in all that relates to the police, to the water supply, paving, and lighting, and the relatively small sizes of the towns, compared with those of modern times, rendered some details in the disposition of houses indispensable, or at least not objectionable, which would not now be tolerated. Thus for instance, the basements of the houses were necessarily built in a substantial manner in order to resist sudden attacks by thieves; the shops, stables, magazines were established on the ground floors, and too often actually on the ground; in the narrow-confined court-yards were placed the cesspools, and the well; and as may still be seen in the old houses of Bruges, Rouen, &c., access was gained to the upper stories by means of narrow, dark, spiral staircases. The fiscal regulations of the various states seem to have led in some cases to peculiarities in the selection of the building materials employed; as for instance when the Dukes of Normandy levied an *octroi* on stone, the inhabitants of Caen and Rouen adopted the use of wood; and, at a more recent period still when, during the reign of Louis XIV. an *ordonnance* of the police limited the height of stone walls facing upon a street, the system of wood roofs covered with lead or slate, known as the Mansard roofs, was adopted. It is to be observed that the houses built during the middle ages very rarely had party walls, and that, like the houses in the modern Dutch towns, each dwelling had its entire enclosure. Under these circumstances the architecture of each particular house had greater scope for originality; and, as in the majority of cases the gable ends of the house face the street, there is usually a very varied and picturesque sky outline in the towns of the period thus referred to. The interiors of the houses were, however, very rude, and we should now say, very uncomfortable. Ceilings were not known, the upper floors were roughly executed with wide planks nailed upon square beams; and Erasmus even tells a sad tale of the filth and abominations the floors were made to support. The windows were not always glazed; those of the shops especially being left open by day and closed by shutters at night, (just as the windows of the shops in Spain, or the less civilised nations, are at the present day) whilst heavy iron bars served to protect the openings against nocturnal marauders; signs swung over every shop, and the water from the roofs was poured directly into the street through grotesque gargoyles.

An important law with respect to the development of the intimate perception of æsthetical principles may be derived from the history of house or of domestic architecture, namely, that precisely in proportion as the individual feeling, so to speak, of the members of society was able to cast aside the trammels of the social tyranny inherent to the political organisations of the ancient world, so were the moderns able to develope a form of art which can hardly be said to have existed at a period when the only classes were the masters and the slaves, and personal liberty of action was sacrificed to the interest or to the political system of the state. Thus, in Greece and Rome we find that the palaces of the wealthy were replete with every description of luxury, and that they were built in a manner sufficiently solid to last to the present day; whilst hardly a trace can be discovered of the dwellings of the middle classes, or of the poor. During the middle ages, the feeling of individual responsibility which is the key-note, as it were, of our modern civilisation, was gradually developing itself; and when the Reformation of the 15th century brought that feeling home to its partisans and enemies alike, all the slumbering energies of our race were urged into the feverish activity which is still carrying us onwards. Domestic architecture, like every other branch of art, participated in the movement; and it is from the middle of the 16th century that we may date the greatest improvements of this branch of the arts. The houses of the period of our Elizabeth, of Henri IV., of the early days of the Dutch republic, were as distinctly in advance of the inconvenient and rudely constructed houses of the antecedent periods in their internal arrangements, as the best modern houses are in advance of them; and it is to be observed that the æsthetical character of the buildings then erected began to assume the personality of the artists, and to reflect the tastes, feelings, and modes of thought of the parties erecting them. No doubt the houses of antiquity and of the middle ages were in accordance with the spirit of their times, but that spirit was a national, a political, or a theocratic spirit, no wise a personal one; nor was it until the period of the Reformation that the style of art which gave rise to the dwellings of such towns as London, Paris, and Berlin, or Munich, can be said to have arisen. And it may also be observed that the peculiar expression of the art in every country of modern Europe may be connected with its social and political constitution; and that they who know how to observe, may easily trace the influence of national laws and national faith in every detail of house architecture in nations possessing a decided autonomy.

Without dwelling on this abstruse question, it may suffice here to say that the modern houses of the civilised nations of Europe and America may be divided into two classes, namely, those which are specially intended to receive one family only, and those which comprise several distinct residences under the same roof. Unquestionably the former class of houses is for many reasons superior to the latter, so far as regards the comfort of the inhabitants, and, it may be more than suspected, as regards its influence upon the general tone of morals, for the love of home can hardly co-exist with life in a kind of common hive; but at the same time, the larger houses which it is necessary to build for the second class admit of a bolder and more ornate style of handling, and of the introduction of a more palatial character. It thus happens that the houses of England and of Holland, where the first class of houses prevails, are deficient in grandeur of external character; and that those of France, Germany, and Italy, where the second class prevails, in the large towns at least, are so much more imposing.

It would be impossible in a short article to trace the rules which are usually adopted in the construction of either of these classes of houses with respect to their interior details; because the requirements of the tenants, their occupations, and their conditions of fortune, necessarily introduce an endless variety; and, moreover, the modifications of climate itself render it necessary to adopt different arrangements in one country from those which would prevail in another. There are, however, some invariable rules to be observed in all good house-building, which may be briefly stated as follows:—

1. The external walls must be constructed of such materials, and of such thicknesses, as to protect the dwellers in the houses from the inclemencies of the external atmosphere, and from the noise of the streets, if possible, when the houses are built in towns. Precautions must be taken to prevent damp from rising in the walls by the capillary action of their materials, and to prevent the communication of fire from house to house. None but the densest and most impermeable bricks or stones should be employed in the external walls of town dwellings, and the most decidedly hydraulic limes should be used in connection with them. In country districts the old half-timbered houses may be tolerated; but neither they nor the cob-walled houses are desirable: in order to keep the walls dry, the eaves of the roof must be continued downwards beyond the top of the wall and projected from it. As far as possible, the openings for doors and windows should be immediately over one another; and it is desirable to avoid constructing a fire-place or flue in an external wall.

2. The materials used in the interior works of houses should be of a partially absorbent and non-conducting nature in cold damp climates; but in warm dry climates, on the contrary, the denser and more rapidly conducting materials may be used. The openings made for the sake of light should be filled in with the most transparent, but also the least diathermal, glass. As far as it is possible to secure that arrangement, the openings for air and ventilation should be made in the walls exposed to the direct action of the sun's rays; and windows looking towards the north should be avoided, unless it be in tropical countries.

3. The sizes and number of rooms in houses must be regulated by the social condition and the number of members of the families inhabiting them, with this simple rule, which is applicable to them all,—namely, that in the sleeping apartments, not especially provided with apparatus for producing artificial ventilation, a cubical capacity of not less than 700 feet should be provided for each person. It cannot, however, be too often repeated, that no sleeping room ought to be constructed without some provision for the renewal of the air affected by respiration; and, therefore, if there should be no fireplace in the room, ventilators must be provided. As a general rule, also, no sleeping rooms should be constructed in the roofs of houses, because the materials of which the latter are composed are not usually able to resist the effects of variations of temperature. In the best houses, the kitchens, sculleries, and offices are detached from the living rooms; though in London, and indeed in the majority of English towns, they are commonly placed in the basements, care being taken to prevent the smell of the cookery from pervading the house. Under all circumstances, the water-closets, or other analogous conveniences, must be erected in such parts of the building as to allow of their having free communication with the external air. Wherever basements are used for dwelling purposes, they ought to be constructed so as to leave at least one-third of their height above the ground-line, and to present a clear space in front of the external walls equal at least to the depth of the floor-line from the ground-level. The floor, whether of wood or of

stone, should be laid hollow, and an efficient ventilation be established under it. A clear space, or back yard, equal in area to the house itself, ought to be provided to all town dwellings.

4. The old classification adopted in the metropolis, by which houses were grouped as 1st, 2nd, and 3rd rate houses, presented some advantages, at least for descriptive purposes; and as the minimum dimensions of rooms adapted to the respective rates have been settled with a tolerable degree of accuracy, they are appended; as memoranda, rather than as rules.

a. The poorer descriptions of 1st rate houses had front sitting-rooms 15 feet wide, by 14 feet long, by 10 feet high; passages, 5 feet wide; well-hole for staircase, 6 feet 2 inches wide; back rooms, 13 feet 9 inches wide, by 14 feet 3 inches long; in all cases clear of walls or partitions of any kind. The basements were made 8 feet clear height; the bed-rooms about 9 feet high.

b. The poorer descriptions of 2nd rate houses had front rooms 13 feet wide, by 13 feet 6 inches long, by 9 feet high; passages, 4 feet 3 inches wide; well-holes 5 feet 4 inches wide: back rooms, 13 feet 6 inches long, by 12 feet 6 inches wide. The basements were made about 7 feet 6 inches high; the bed-rooms from 8 feet to 8 feet 6 inches high.

c. The poorer descriptions of 3rd rate houses were made with front rooms 10 feet 9 inches wide, by 11 feet long, by 8 feet high; lobbies, 3 feet wide leading to staircase, in the middle of the houses, 2 feet 9 inches wide; and back rooms the whole width of the house by about 10 feet 6 inches deep. The bed-rooms were made from 6 feet 6 inches to 7 feet high.

5. It may be as well to add that, in towns, it would be desirable to make the width of alleys (or the passages for foot-passengers only), not less than 15 feet; and to limit the height of the houses to the same dimension, measuring from the ground line to the top of the wall-plate of the roof, when the ridge is parallel to the front; or to the top of the parapet, if the roof be made in the form known as a hipped V roof. When, however, houses face upon streets in a continuous line, the height may be made equal to the clear space between the front walls on the opposite sides; but as in case of fire it is difficult to force water to a greater height than 70 feet, it may be suspected that the above limit (namely, 70 feet), ought to be adopted for private residences. The width of streets, of course, will be regulated by the amount of traffic they are likely to receive, but it may be said to range between 40 and 80 feet, including the footpaths.

HOUSEBREAKING. [LAW, CRIMINAL.]

HOUSE OF CORRECTION. [PRISON.]

HOWITZER, a piece of ordnance which is constructed to throw shot and shell of a large calibre at short ranges. The gun being comparatively very light, the charge of powder is small, and consequently the angle of elevation required is high. It may be considered intermediate between the gun and the mortar; though it is mounted on a gun-carriage. It derives its name from the German word *haüfen*, "to fill." The name perhaps did not at first indicate a distinct species of ordnance, but was applied to any gun filled or charged with slugs or case-shot. Short guns for the discharge of shells were used in Italy in 1618; but they do not appear to have been introduced into France till 1683, about which time they were also adopted in the British service. Howitzers are made of brass and iron; the former forming a portion of field-batteries, the latter of siege-trains and garrison artillery. The brass howitzers are denominated 24-pounders, 12-pounders, 5½-inch, and 4⅖-inch, from the weight of the round shot which they will carry, and the diameters of the shells discharged from them. The iron howitzers are the 8-inch and 10-inch. Their lengths are respectively:—

Iron, 5 feet, and 4 feet.

Brass, 4 feet 9 inches, 3 feet 9 inches, 2 feet 8 inches, and 1 foot 11 inches.

The fire of shells from brass howitzers in the field is found very effective against villages, stockades, palisades, &c. The iron howitzers are used in sieges, principally for RICOCHET.

The modern shell guns [ORDNANCE] are a description of howitzer.

HUE AND CRY was the old common-law process of pursuing with horn and voice all felons and such as had dangerously wounded another.

Though the term has in a great measure fallen into disuse, the process is still recognised by the law of England as a means of arresting felons without the warrant of a justice of the peace. Hue and Cry may be raised either by the precept of a justice of the peace, or by a private person who knows of the felony; who should acquaint the constable of the vill with the circumstances and the person of the felon; though, if the constable is absent, hue and cry may be made without licence. When hue and cry is raised, all persons, as well constables as others, are bound to join in the pursuit and assist in the capture of the felon. A constable also who has a warrant against a felon may follow him by hue and cry into a different county from that in which the warrant was granted, without having the warrant backed. The pursuers are justified in breaking the outer door of the house where the offender actually is, and are not liable to any punishment or suit if it should appear that the hue and cry was improperly raised, but the person raising the hue and cry wantonly and maliciously may be severely punished as a disturber of the public peace.

HUGUENOTS was the name given to the early followers of the Reformed or Calvinist religion in France. The origin of the name has been variously accounted for. It is said to be derived from the German word "Eidgenossen" ("bound together by oath"), which was the name assumed by the confederate cantons of Switzerland, and which was afterwards adopted by those citizens of Geneva who promoted the alliance of that republic with the cantons of Fribourg and Bern, in opposition to the partisans of the duke of Savoy, who were called Mamelucs, that is slaves. The word Eidgenossen, being transferred into the French language, was corrupted first into Eguenots, and lastly Huguenots. (Bérenger, 'Histoire de Genève.') It is also said to have been derived from the early meetings having been held on a heath near Tours, haunted by the ghost of Hugo Capet. When the Reformation began at Geneva, the party which favoured it, being in great measure the same which had supported the Swiss alliance, retained the appellation of Eguenots, or Huguenots, and as several of the early French reformers came from or were connected with Switzerland, and especially with Geneva, the name spread into France, and was applied to the partisans of religious reform during the times of religious war and persecution. The Roman Catholics used the name of Huguenots as a word of reproach against heretics. The word is now obsolete, and has been replaced by that of "Réformés," which is given chiefly to the disciples of Calvin, while the more general name of Protestants includes the Lutherans. The war and persecutions of the Huguenots are matters of history, but a good account of those of the Calvinistic branch has been given by Dr. G. De Félice, in his 'Histoire des Protestants de France depuis l'origine de la Reformation jusqu'au le temp present,' 1850, of which there is more than one Englisht ranslation; 'De l'etat des Protestants en France,' by Aignan, 1818; and Merle d'Aubigné's 'History of the Reformation in the 16th Century,' 1835, &c.

HUMIC ACID. [GEIN.]

HUMIDITY is that property of a substance by which it communicates to a body in contact with it some of a liquid which it may have absorbed; and the term is commonly applied to the atmosphere when it is in a state to deposit moisture upon bodies in it.

The humidity of the atmosphere is caused in a great measure by the evaporation of water from the seas, lakes, &c., of the earth; and the quantity of moisture which a volume of air is capable of containing depends upon the temperature: when the latter is low at any part of the earth's surface, the air may be saturated with moisture so as to be incapable of holding any more, but the quantity of moisture in a given volume will then be small. If the temperature be increased, the atmosphere, becoming thereby comparatively dry, acquires immediately the power of receiving more vapour, and the power increases with the temperature, so that, in a given volume of air, the quantity which consists with the state of saturation is also increased. Whatever be the quantity of vapour which constitutes the state of saturation, if the temperature be suddenly lowered, or if there be presented a body which has an affinity for water, a precipitation of the latter takes place, or water becomes absorbed in the body. [DEW; EVAPORATION; HYGROMETRY; RAIN.]

The temperature of the atmosphere over any place on the surface of the earth diminishes as the distance of the stratum of air from the surface increases: the power of the air to hold vapour diminishes accordingly; and, as a general law, it may be stated that the humidity of the atmosphere decreases from the surface of the earth upwards. The great dryness of the atmosphere near the summits of mountains has been frequently remarked by travellers, but the quantity of moisture in the different strata is, from local influences, subject to many irregularites. The temperature of the lower strata of the atmosphere diminishing as the latitudes of places on the earth increase, a given volume of air, as a cubic foot, when completely saturated, will contain less water as a station is farther from the equator; and the like may be said of the entire column of the atmosphere over a station. This may serve to account for the fact that, in general, the weather becomes fine when the mercury rises in the tube of a barometer; for then, by the increased density of the air, the clouds are made to ascend in the atmosphere to a region where, the dryness being great, they are readily dissipated. On the contrary, when the mercurial column diminishes in length, the clouds descend; and arriving near the earth, they enter a region in which the atmosphere is at or near the state of saturation; when, consequently, the vapours are easily precipitated. Biot observes, on this subject, that the descent of the mercury is a more certain prognostication of rain than its ascent is of fair weather; the ascent of the clouds in consequence of an increased density of the air not being necessarily accompanied by their dispersion. From the agitation produced by high winds, the upper regions of the atmosphere are often charged with aqueous vapour; and rain may then fall while the top of the column of mercury is above its mean height, and even while it is rising in the tube.

The atmosphere often becomes humid from the evaporation of liquids by artificial means. In establishments for brewing, dyeing, and the like processes, the vapours produced from liquids which are constantly in a state of ebullition rise in the atmosphere, and even render it opaque. The breathing of men and animals produces a watery vapour which renders the atmosphere humid; and when a number of persons are assembled in a close apartment the humidity is sometimes so great that water flows down the walls. The leaves of plants also discharge, in the form of vapour, the water which is imbibed by the roots; and in conservatories this effect is particularly sensible.

In order to determine the quantity of water which is contained in earth when completely saturated with rain, Dr. Dalton took a quantity of garden mould, on which rain had fallen copiously during the preceding day, and exposed it to different degrees of heat. When it seemed to have about the same degree of moisture as soil at the depth of two inches from the surface in dry summer weather, he weighed it, and found that it had lost one-twelfth of its weight; and when it had lost two-ninths of its weight it seemed like the upper soil in summer. His conclusion is that a body of earth one foot in depth, when saturated with moisture, contains seven inches in depth of water, and that it may lose one-fourth or one-half of that quantity without becoming incapable of supporting vegetation.

The effects of humidity on the dimensions of bodies are various: when a watery vapour penetrates between the twisted fibres of cordage, which are vegetable materials, the cordage swells out transversely, and thus becomes shortened; while cords made of animal substances become relaxed by humidity and increase in length. Most salts absorb water, and thereby increase in weight.

HUMIN. [Gein.]

HUMOPIC ACID. [Humopinic Acid.]

HUMOPINIC ACID ($C_{48}H_{23}O_{17}$, or $C_{40}H_{20}O_{14}$?). *Humopic Acid.* A product of the decomposition by heat of narcotine, which on being melted and exposed to a temperature of 428° is suddenly decomposed, with considerable intumescence, into ammonia and a brown vesicular substance, which consists chiefly of the acid in question.

This acid is a dark brown amorphous body, which melts on exposure to heat, and burns with a bright flame, diffusing an odour resembling that of narcotine. It is soluble in water, dilute acids, and in alcohol, giving with the latter a deep red-coloured solution. With the alkalies it forms saffron-yellow coloured solutions, which give dark brown precipitates with the salts of baryta and lead. When humopinic acid is boiled for some length of time in water, it becomes insoluble in ammonia, and, when added to potash or alcohol, a blackish brown substance remains undissolved, which is probably humin. Its composition has not been determined with certainty.

HUMULUS LUPULUS, MEDICAL PROPERTIES OF. [Hops.]

HUMUS. [Gein.]

HUNDRED. [Shire.]

HUNDRED COURT. [Courts.]

HUNDREDWEIGHT. [Avoirdupois; Weights and Measures.]

HUNS, HUNNI, the name given by historians to several nomadic Scythian tribes, which devastated the Roman empire in the 5th century. It appears that these people inhabited the plains of Tartary near the borders of the Chinese empire for several centuries before our era, and that they were known to the Chinese by the name of Hiong-nu, and also Han. They made many incursions into China, and it was to put a stop to them that the Chinese built their great wall, about two centuries B.C. In after-times they became divided into the Northern and Southern Huns. The Northern Huns, being defeated by the Chinese about A.D. 93, emigrated westward as far as the Volga, where they met the Alanni, or Alani, another powerful Scythian tribe, which they routed and drove beyond the Tanais, or Don. The Huns then encamped in the plains between the Volga and the Tanais, and as far south as the ridge of the Caucasus, where they remained for more than two centuries. Under the emperor Valens, they first crossed the Cimmerian Bosporus, drove before them the Ostrogoths and Visigoths, and obliged the latter to cross the Danube, when the emperor granted them lands in Thrace. The Huns were joined by numerous other Scythian hordes, and were looked upon with equal dread by the Gothic and Teutonic nations and by the Romans. Their features and general appearance are described by the Roman historians as hideous and repulsive, and their manners as savage in the extreme. ('Ammianus,' b. 31.) The description of their features seems to correspond in some degree with that of the Calmucks of the present day. The Huns being now on the frontiers of the empire, had frequent wars with the Romans, and their incursions were dreadful though not lasting. [Attila, in Biog. Div.] After the death of Attila the various tribes under his sway quarrelled among themselves, and being attacked by the Goths they were driven back beyond the Tanais. Part of them settled in Pannonia, to which they gave the name of Hungary, but the present Hungarians, or Magyars, come from a different and much later immigration. The Huns are mentioned in subsequent history as being sometimes at war with the emperors of Constantinople, and at times as their allies against the Persians. Under Heraclius many of the Huns embraced Christianity. After that period their name is no longer mentioned in history. (Des Guignes, 'Histoire des Huns.')

HURIN. An acrid non-azotised crystallisable substance obtained from the juice of the *Hura crepitans.*

HUSBAND. [Divorce; Separation, Judicial; Wife.]

HUSBANDRY. The origin of the simplest arts of life is involved in the obscurity which envelopes the early history of the human race. Before there can be any motives to record events, some considerable progress must have been made in civilisation. When attention is altogether directed to obtaining the means of subsistence, there is little leisure; nor is there any great desire to communicate the knowledge acquired by experience. Warlike achievements are the first things recorded; and the peaceful labours of the husbandman are overlooked. In the fables which in the early ages of the world supplied the place of authentic histories, some conspicuous character was always made the inventor of the various arts of which the origin was unknown; and to such personage a divine origin was frequently ascribed. Thus Cadmus is said to have invented letters, and Triptolemus to have made the first plough.

In the oldest writings which have been handed down to us, the common operations of husbandry are mentioned, or alluded to, in nearly the same terms in which we should describe them now—the same implements were then in use, and the same productions raised which are now found in the same climates: but they are only mentioned incidentally. It requires a very advanced state of the arts and of literature to produce a treatise on any one practical subject exclusively; and the simpler and more common the arts, the less they are noticed in the early literature of a nation. We have, however, no other means of tracing the progress of husbandry than by the works of those who have written on the subject, until we come to our own times, when everything is noted and commented on, and every one who makes any discovery or improvement is anxious that the public should be acquainted with it. We have already mentioned some of the early Greek authors [Arable-Land], and likewise some of the Latin authors most generally known as having treated of husbandry in general. ('De Re Rustica.') From these authors we learn that considerable progress had been made in the tillage of the ground and in the breeding and rearing of domestic animals: and it appears that wherever the Romans carried their victorious arms, they also introduced improved methods of cultivation. The practice of fallowing land, to restore its fertility, can be clearly traced to them. For a long time the Latin authors were the source from which all writers on husbandry derived their knowledge; and hence many useless and absurd rules, which were connected with the pagan superstition were perpetuated.

The Mediterranean Sea and the countries situated around it were once the centre of all the arts, which had slowly travelled westward from Asia and from Egypt; and the colonies which the Greeks and Romans planted on all the coasts of this sea, and in the countries which they conquered, contributed to diffuse a knowledge of the various products of the earth. The irruption of the barbarians into the Roman empire greatly checked the progress of husbandry; but the destruction of the Eastern empire, while it made the Greeks retrograde in civilisation, tended to introduce improvements into those countries where men of learning and science sought a refuge from the invaders.

British Husbandry.—The husbandry of the aboriginal Britons was probably very imperfect before the invasion of Julius Cæsar; but we have no records to inform us. Rural matters were of too little importance in the eyes of conquerors to engage much of their attention, but the mildness of the climate and the general fertility of the country, induced many of the Romans to settle here; and from them the natives learned a better system of cultivation than that of their ancestors.

As far as we can learn from ancient documents, the land in England formerly consisted chiefly of woods and of extensive pastures, in which sheep and cattle were bred, which constituted the chief wealth. A very small proportion of the soil was cultivated; and while the population was thin, there was no difficulty in obtaining land which had never before been broken up, and which with little trouble or manuring produced moderate crops of corn. But this system could not last long. The proprietors of land would soon perceive that the produce fell off, and would consequently restrict the breaking up of pastures, and thus more attention was necessarily paid to the arable lands in cultivation.

Through the deficiency of the laws, or the difficulty of executing them, and the frequent intestinal wars between the barons, depredations were often committed with impunity; and the cultivators of the soil congregated in villages for mutual protection and defence. The best land nearest to the habitations was cultivated, and the common pastures fed the cattle without much trouble or expense. The consequence of this system was, that very little manure was made, and the cultivated fields scarcely produced a return adequate to the expense of cultivation. Four times the seed was a full average for corn crops, and the land was overrun with weeds after a single crop. Hence it was not an uncommon practice to have a fallow every other year, and this was considered a superior system to having two crops between the fallows, which has been more common since. Wheat was very little cultivated; barley, rye, and oats were the principal produce.

The woods nourished many hogs on the acorns and beechmast which abounded there, and the right of turning hogs into the king's forests was granted under the barbarous terms of *mastagium* and *rootagium.*

The religious orders, to whom extensive grants of waste lands were made, greatly contributed to the improvement of agriculture. The monks, by their knowledge of Latin, were enabled to study the Roman authors on husbandry, and, by applying the rules and principles which they drew from that source, they greatly improved their estates, and made the land more productive: teaching and encouraging their tenants to till the land more effectually, they were, upon the whole, better and more indulgent landlords than the nobles, who, provided they secured retainers and supplied their households with necessaries, gave themselves little trouble about anything else. Bread made of rye, barley, peas, or beans, was the principal food of the labourers, who were attached to the soil, and had no right to remove to another place or serve any other master. The immediate tenants of the lord of the soil cultivated a portion of the lands which they held for their own use, and let the remainder to smaller tenants, who, although born free, were little above the condition of the labourers, and lived much in the same manner. There was so little capital among the farmers, that the live stock was frequently the property of the landlord, and was let with the land, as well as the servants. As to implements, they were very few in number, and rudely made by the farmer himself; an iron plough-share, an axe, and a spade, were the principal instruments for which he had to pay.

Oxen, which could be kept on the common pastures at little expense, were used for the plough; and so badly fed were they in general, that it required six oxen to draw a plough, which barely turned up half an acre in a summer's day. These oxen consumed all the straw of the farm in winter, and little was left to make manure of. Horses carried the corn to the mill or market on their backs, the roads being mostly impassable for wheel-carriages, which indeed were unknown in many parts of the country.

These particulars can only be gleaned out of various authors, who incidentally mention the state of the agricultural population, and from ancient deeds and documents.

With the revival of letters, and especially with the invention of the art of printing, greater attention began to be paid to rural affairs: but all the early English or foreign authors who touch on the subject of agriculture took their notions from the Latin writers *De Re Rustica*, and rather say what should be done, than what really was done.

The first English author of any note who wrote on husbandry was Sir Antony Fitzherbert, who has by many been looked upon as the father of English husbandry. He published his 'Book of Husbandrie' in 1523. This work throws considerable light on the state of the farmers in those days, who, with their wives and children, worked hard, and were little raised above the common labourers, except that they were freemen. A yeoman who had land of his own was a very independent man; but his mode of living was extremely plain, and he had no luxuries. Money was seldom seen in his possession. He lived on the produce of his land, and fed his labourers at his own board. Wool was the principal article sold. The sheep were kept on extensive commons, at little expense; and in some places the folding of them on the land was the principal mode of recruiting it when exhausted. The great difficulty was to keep them alive in severe winters, and many perished every year. The only provender they had was hay; and as artificial grasses and turnips were unknown, natural meadows paid an enormous rent, when compared with arable land. For want of winter provender for cattle, many were killed which were not sufficiently fat. Very little fresh meat was eaten after Christmas, and every family had oxen and sheep killed and salted in autumn to last till the next summer.

In the time of Elizabeth some attention began to be paid to the improvement of husbandry, but no works of any note have come down to us in which we can discover that any considerable change was made in the common modes of tillage or in the rearing and feeding of cattle.

The situation of the farmers however appears to have improved: they began to acquire wealth and to increase their domestic comforts. The farm-houses were more solidly built and commodious, having before been chiefly constructed of wood, and the walls plastered with clay.

Cromwell encouraged husbandry, and gave a pension to Hartlib, who published in 1641 a work on the husbandry of Flanders, and another in 1651, called the 'Legacy of Husbandry.' Walter Bligh, the friend and contemporary of Hartlib, published in 1652 another work called 'The Improver Improved.' This work is deserving of notice. It contains very sound principles of husbandry, with many excellent observations, which may be of great use even in our days. The author mentions clover as an important object of cultivation introduced from the Netherlands; and he may be considered as the first who recommended sowing this plant for feeding cattle. Sir Richard Weston, who soon after gave an account of the cultivation of turnips in Flanders, laid the foundation of the improved system of husbandry, of which the feeding of cattle and sheep on turnips in winter is the chief feature.

From that time till the present day husbandry has improved slowly but regularly. With the increase of population and a consequent increased demand for the produce of the soil, there has arisen a new species of speculation, that of reclaiming waste lands, by which the estates of many landed proprietors have been greatly improved. But the most important step has been the granting of long leases to those who were inclined to lay out their capital and employ their skill in improving farms. The security which the law gives to a leaseholder and his independence of his landlord, provided the rent be duly paid, affords the greatest encouragement to industry; and it will be invariably found that the improvement of any district is proportioned to the length of time for which leases are granted there, at a fair annual rent, without uncertain fines.

The spirit of improvement and the hope of increasing his income often lead a man to mistaken experiments and consequent loss; but the experience thus gained is always valuable to the community. Jethro Tull, a gentleman who had a property near Hungerford in Berkshire, introduced a mode of cultivation which was prevalent in Lombardy, and was borrowed from the practice of gardeners, who sow and plant their vegetables in rows with wide intervals. Finding that in rich soils the produce was much increased by stirring the earth round the roots of plants, he formed a theory respecting the food of plants, which he imagined to be extremely finely attenuated "earth." He thought that manures acted only mechanically, and that by continually stirring the soil it might be kept perpetually fertile. The attractive part of this theory was, that whereas the supply of manure is limited, there is no limit to labour, and that consequently an increase of population only required an increase of tillage to supply it with food. Tull was admired, and his theory adopted by many eminent men. His practical system, to which the name of *drill-husbandry* has been given, was looked upon as one of the most important discoveries. Notwithstanding that his imagination led him too far, he must be considered as one of the great promoters of good husbandry. Even his errors have been useful by making men observe and reflect; and the introduction of machines to drill the seed in rows, and of others to clean and hoe the intervals, which he principally suggested, has been of infinite use to the improved cultivation of the soil.

The rearing and fattening of cattle on the produce of arable land, which followed the introduction of sainfoin, lucern, and other artificial grasses, and the cultivation of roots for the same purpose, have made a great change in the old systems. Manure is produced in greater quantity; the land increases in productive power, and will bear more frequent crops of corn; better implements have been invented to save labour and to do the work more completely; and a system of draining has been introduced, which has corrected the great fault of most strong soils in northern climates—excessive moisture, which cannot evaporate. Many causes have concurred to produce these improvements. At one time high prices induced men to lay out their capital on the cultivation of the soil; at another, low prices stimulated industry to make up by an increased production for a deficiency in the value; and what has contributed greatly to keep attention directed towards agricultural improvements is, the rapid increase of the means of communicating information by the press. Every successful experiment, every new method which the inventor thinks of importance, is speedily announced to the public.

The improvements which have been made in the breeds of cattle and sheep may be considered as entirely modern. The profit which some eminent breeders have made, and, to some extent, still make, by their attention and their skill, is a sufficient inducement to excite competition. Mr. Collins and Mr. Bakewell may be cited as examples of successful attention to breeding. Mr. Collins obtained at a public sale of his cattle—

For 17 cows of all ages	£2669
For 11 bulls	2249
For 7 bull-calves under one year old . . .	655
For 7 heifers	808
For 5 heifer-calves under one year . . .	306
Making for 47 head of cattle of all ages . .	£6687

And such prices have been, since his time, of late years rivalled by the sales of well-bred stock.

To enumerate the various works which have come from the press on subjects connected with husbandry would be to give a catalogue of a large library. We can only mention some of the principal authors, such as Lord Kames, Marshall, Arthur Young, Sir John Sinclair, and Dickson. Of these, the most original author is perhaps the first. But the works of Arthur Young are those which afford the fullest information on the state of British husbandry in the latter half of the 18th century, and did most towards its general improvement. The 'Farmer's Magazine,' which appeared in 1800, and continues under a new set of editors to this day, has done much good in disseminating useful practices in husbandry. British husbandry owes much to the zeal and activity of individuals who have formed societies for its improvement. The Bath and West of England Society, which still exists, and has of late years greatly extended its operations, has been very instrumental in spreading the knowledge of practical husbandry, and much useful information is contained in the Reports of its Transactions. The Highland Society of Scotland, of which all the principal proprietors and most of the large occupiers of land in Scotland are members, has greatly contributed to encourage experiments, and to promote improvements in every branch of husbandry.

The Board of Agriculture, at the head of which was Sir John Sinclair, the zealous promoter of all measures for diffusing agricultural information, although it rather disappointed the hopes and expectations formed at its commencement, and has for some time ceased to exist, was the means of diffusing a knowledge of the state of husbandry throughout Britain, at the beginning of this century, by the publication of the Agricultural Surveys of the different counties, the substance of which was condensed in the 'British Husbandry,' in 2 vols., published under the superintendence of the Society for the Diffusion of Useful Knowledge. The English Agricultural Society, and the other national agricultural associations, have also been influential in giving a new stimulus to the improvement of British husbandry.

To complete this short sketch of British husbandry, it only remains briefly to mention the different systems which have been most prevalent at different times.

The first and most inartificial is that which consists in breaking up portions of pasture-land and sowing corn on a slight ploughing, which cannot fail to be productive for some time. Several crops may thus be taken, until the land is so exhausted, that the crop no longer repays the seed and labour. To defer this time, experience soon pointed out the crops which succeeded best after each other. Wheat or barley were probably the first crops; afterwards peas, beans, or oats, until the ground, being overrun with weeds, would be left to the renovating effect of time, and a fresh spot would be broken up.

The first improvement on this system is that of infield and outfield. The infield is cultivated more carefully, somewhat like a garden, and all the dung of the cattle is exclusively put upon this part. The outfield is a continuation of the first-mentioned system. The infield consisted of inclosures or open fields near the dwelling, which it was most convenient to cultivate as arable land. Thus two distinct systems of husbandry were carried on at the same time; and whatever improvements were introduced in the management of the infield, the outfield continued to be managed as it was before.

The mode of recruiting by means of a fallow lands which had been exhausted by crops, or were overrun with weeds, seems to have been introduced into England by the Romans; but appears not to have been practised in Scotland till the 18th century. The differences in Scotland of the mode of tenure from that of England, and the little peaceful intercourse of the two countries, may perhaps in some degree account for the non-adoption of the summer-fallow. The alternate crop and fallow seem to have been later introduced than a fallow after several crops. The triennial system, which consists of a summer fallow, a winter crop, and a spring crop, was probably longer established than any other, and is still the practice in many parts of England. The deteriorating effect of the outfield system would lead to its abandonment as soon as population increased, and with it the want of land for infield. The common-field lands, which were so extensive till within the last fifty years, many of which have since been inclosed by special acts of parliament, were probably at first only portions of commons, which were broken up by common consent, and formed into outfields. The right of pasture over them, after the crops are removed, strengthens this supposition.

When common-fields are divided and inclosed, a better system of husbandry generally follows. Clover and turnips are more regularly sown, and, on light lands, take the place of summer fallow. Clover generally comes after a crop of corn, in which it was sown the preceding year in spring; and as most crops succeed well after clover, wheat was usually chosen for the next crop as the most profitable. Thus arose the Norfolk system, without any very sudden departure from the old rotations. Two crops raised for the food of animals in four years require more cattle on the farm to expend them profitably: and thus more manure is made. In the light soils the sheep when folded on the turnips not only enrich the land by their dung and urine, but likewise render it more compact by treading it, which is advantageous to the clover and wheat which come after. If the land is a good loam, beans are sometimes sown after wheat, the land having been recruited with manure; and if the beans are kept clean by hoeing another good crop of wheat may be obtained after them. Thus arises the improved rotation of turnips, barley, clover, wheat, beans, wheat; after which the land is again cleaned and prepared for turnips with all the manure that can be spared. As in this system there is always a crop with succulent leaves intervening between two which have a white straw, it has been called the *alternate* system of husbandry. These are the most common systems in England. The removal of the fallow year, provided the land be kept clean, is a decided step towards improvement. The best farmers effect this by the introduction of artificial grasses and tares fed off by sheep, and especially by sowing every crop in rows and keeping the intervals stirred, which is a partial fallow without losing a crop. Here Tull's system is introduced, which in its complete state, as the author recommended it, was soon abandoned.

As the English systems have taken their origin chiefly from the infield cultivation, so the Scotch appear to have arisen from that of the outfield. Fallows were unknown; but the invigorating effect of grass fed off by cattle must soon have been perceived; and instead of leaving the land to recover slowly by the spontaneous growth of natural herbage, which on poor land takes a long time, it was obvious that this might be accelerated by sowing grass-seeds. Hence the origin of the Scotch convertible system of husbandry, which is gaining ground daily, and bids fair, in remote situations where no manure can be purchased, to be firmly established. The order of the conversion has been somewhat altered from what it was originally. Instead of sowing grass-seeds after the land is exhausted, it has been found advantageous to accelerate the growth of grass by manuring the crop in which it is sown; and experience has proved, that the richer the grass is, the more productive are the crops which come after. The grass, instead of being a mere substitute for fallowing and manuring, is made highly profitable by feeding cattle and sheep; and the profit of the years when the land rests, as it were, by being depastured, is often as great as that of the years when it is cropped; and the risk and expenses are much less. The convertible system is not very generally known or adopted in England, and is often confounded with the alternate system. The alternate system interposes a green crop between two white-straw crops. On good land the convertible husbandry may consist of three or four years' tillage and three years' grass. If the land is not quite clean, a summer fallow on heavy soils, or a turnip fallow on light soils, should begin the course; and only one crop should be taken after the fallow in which the grasses are sown, whether it be wheat, rye, barley, or oats. It should be fed off the first year, mown the second, and fed off again in the third; when it is broken up, oats are usually sown as the first crop in Scotland, then beans, if the land admits of them, and then wheat. If a fallow is intended, a crop of peas may be sown after the wheat, and then the course begins again, as before, with a clean fallow or with turnips. In this manner the land may be kept clean, and continually improve in fertility by means of the cattle which are kept upon it, without the aid of any purchased manure, except lime, the expense of which is in most cases well repaid by the crop. These are the only regular systems in Britain; and every mode of cultivation and cropping may be reduced to one of them, unless it be capriciously anomalous. Of late years Tull's husbandry, applied to the perpetual succession of wheat crops on the same land, has been developed and somewhat modified; and, now known as the Lois Weedon system, has been pretty extensively tried. The Rev. S. Smith, of Lois Weedon, has the merit of having thus recalled the maxims and experiments of Jethro Tull to the favourable notice of English agriculturists.

What renders the improved systems of British husbandry so superior to that of all other nations is the attention paid to the perfection of the different breeds of domestic animals, especially the horse, the ox, and the sheep. In this respect British husbandry surpasses every other. No expense or trouble is spared to improve the qualities of cattle and sheep. It has been objected, that the rewards given by different societies for excessively fat cattle are not judicious, as these animals are never profitable to the feeder. The same might be said of very high-bred racehorses; they are not so useful as a good hackney or hunter; but unless some individual animals possess the power, courage, and speed which is the mark of the best blood, it would soon degenerate; so likewise if some oxen were not occasionally fatted to an extraordinary degree, the fatting qualities of the breed could not be proved. A badly bred ox will never become so fat, whatever food may be given him, as one of a choice breed. This the breeders are well aware of, and never hesitate to pay a good price for a young bull of any prize breed.

The great variety of new instruments which are daily invented, and some of which gradually come into use, however expensive they may appear, is another feature in British husbandry; and the letting out of drills and steam threshing machines, which are kept for profit by men who have little or no land to cultivate, is a step to that division of labour which has done such wonders in manufacturing industry, and which will no doubt in time do the same in the operations of husbandry. There is a fresh spirit of improvement arising among practical agriculturists, and not the least favourable symptom is, that it begins to be acknowledged that "much may yet be learned," and that "husbandry is still comparatively in its infancy." The success at length of the reaping machine and of the steam plough is the crowning point of its progress hitherto; and this, conjoined with the extraordinarily developed trade in artificial and manufactured manures, is what indicates most perfectly the energy and enterprise of English agriculturists.

Husbandry in Italy.—It might be expected that Italy would present some remains of the Roman husbandry, but such has been the pernicious effect of wars and intestine commotions, that this fine country, with all the advantages of soil and climate, is far behind less favoured regions in the cultivation of the soil and the rearing of cattle. The plains of Lombardy alone are an exception; but the cultivation of maize, the principal produce there, partakes more of the garden husbandry than that of any other grain. The abundance of water which descends from the Alpine regions fertilises a great extent of soil by artificial channels, in which it is made to disperse itself, and produces a vegetation which requires little assistance, except that of weeding. Italy was however the country where, on the revival of letters, the first books were published on the practice of husbandry. Pietro di Crescenti, a citizen of Bologna, born in 1230, after thirty years' experience in all parts of Italy, wrote a treatise entitled 'Opus Ruralium Commodorum,' printed in 1474. There is a doubt whether it was first written in Latin or Italian, but it was soon translated into French and German. The author quotes Cato, Varro, and Palladius, but not Columella, who probably was not then generally known, or perhaps his works had not yet been rescued from the libraries in which ancient works were long buried. In the succeeding century many of the Greek and Latin authors on husbandry were translated and published. Tavello, in his 'Recordo d'Agricoltura,' 1561, ascribes the deterioration of agriculture to the practice of letting land for three years only, which had been introduced very generally, and perpetuated the triennial system in its worst form. Johannes Baptista Porta, in 1592, published his 'Villæ,' in 12 books, a work which has had a considerable reputation, and is considered by many as still well worth consulting. A variety of authors on different parts of husbandry wrote about this time, in consequence of the frequent famines which arose in Italy from a very imperfect state of husbandry. The 'Vinti Giornate dell' Agricoltura,' Venetia, 1569, which had been first published in 1550, under the title of 'Deci Giornate,' went through more than twenty editions in Italy, besides being often translated. The author ridiculed the foolish astrological notions prevalent at the time, and his work is full of good sense. But all these writers had little influence on the improvement of the actual practice of husbandry in Italy. If a spirited proprietor attempted to introduce improvements, the prejudices and obstinacy of the country people soon disheartened him, and to this day the systems adopted are extremely defective, if there be any system at all. In many places the ploughman still stands on the heel of the plough to keep it in the ground, and a straight furrow is not thought of. The earth is scratched rather than tilled; and if good crops arise from the natural fertility of the soil, they are generally choked with weeds before harvest.

An attempt had been made by Leo X. to drain the Pontine marshes, and it was renewed in 1586 by Sextus V. Pius VI. spent great sums on the same object; but to this day little has been effected; and instead of the fertile plain which once was covered with a golden harvest, there is nothing but a dreary marsh producing pestilential vapours pregnant with disease. Sicily and Sardinia, once the granaries of Rome, now produce only a very small quantity of corn. The best cultivated districts in Italy are Piedmont, Lombardy, Tuscany, and the country about Ferrara; but, except in the two first, they are behind the greater part of Europe in the management of a farm. The proprietor of the land, if he does not cultivate it by his own servants, is usually the proprietor of all the live stock and implements of the farm.

Husbandry of Spain.—Spain possesses a considerable extent of fruitful soil, and the husbandry of the Romans, which the irruption of the barbarians had interrupted, was in some measure revived by the Moors. When they were expelled, Spain lost many industrious husbandmen and manufacturers. A work on husbandry by a Moor, called Ebd-el-awam, who is supposed to have lived about the 13th century, was published with a Spanish translation at Madrid in 1802, and does credit to the agricultural knowledge of the author. The cultivation of the sugar-cane and of saffron are mentioned in this work.

Herrera, who wrote on husbandry at the desire of Cardinal Ximenes, is one of the most esteemed authors of his time. His works have been frequently republished; and are now in great reputation, and looked upon as quite classical in agricultural literature. He laments that mules are generally used in Spain for the plough and other purposes of husbandry, instead of the ox. But Herrera did not succeed in changing the custom; and mules are still in general use. The great object of attention in Spain is the production of fine wool; and the privileges given to the Mesta, a kind of corporation of shepherds, tend greatly to retard the introduction of a better cultivation. The Merino breed of sheep is said to have been imported originally from Britain. But it is evident that, if it is necessary to its perfection that the flocks should run over half the kingdom every year, the profit made by the exportation of fine wool is dearly purchased by the disadvantages of a miserable state of agriculture. Instead of, as from the character of the country she ought, producing a superabundance of grain and supplying other countries, Spain is obliged frequently to import corn in order to prevent a scarcity. The state of Portugal is not better, and the vine is the only plant of which the cultivation is moderately well understood in the whole of the peninsula.

Husbandry of Germany.—The husbandry of Germany varies greatly in such an extent of country. In the time of Tacitus half the country was covered with impenetrable woods. As population extended the forests were cut down, and the sickle succeeded to the axe. The republic of the Swiss cantons and the Hanseatic towns gave the first examples of encouragement to husbandry. In 1571 the work of Heresbach, entitled 'Rei Rusticæ,' libri iv., was reprinted at Cologne. Heresbach was born in the duchy of Cleves in 1509, and is considered the father of husbandry in Germany.

Augustus I., elector of Saxony, wrote a treatise on the cultivation of the vine, which was published in 1636, entitled 'Churfürsten's Augusti zu Sachsen Obstgartenbuchlein.'

In Prussia, Mecklenburg, and Holstein, husbandry has made the greatest progress in modern times. The Prussian government, from the time of Frederick the Great, has taken agriculture under its especial protection. In Prussia there are several schools of agriculture, where this art is taught on scientific principles, and where the practice is shown on large farms. That of Mögelin, over which A. Thaer presided, became conspicuous from the excellent work on rational husbandry, 'Rationellen Landwirthschaft,' which he published. The introduction of the Dutch system of dairying in Holstein, and the breeding of fine horses there, has given a reputation to this part of the Danish dominions. In Bavaria, along the banks of the Rhine, from Basel to Darmstadt, there is a fine fertile plain which is cultivated with some care; and although subjected generally to the triennial system (which is called in England the three-course shift), the husbandry of that part of Germany is not to be despised. In Switzerland the management of grass-lands and water-meadows is carried to great perfection. The cultivation of lucern and sainfoin is very general; potatoes are raised to a very considerable amount; and the soiling of cattle in the stables is universal. The scientific writers of Geneva have contributed greatly to throw light on the theory of vegetation; and it is scarcely necessary to mention Theodore de Saussure, Pictet, De Candolle, and Macaire, as men who have contributed more than any others to explain the functions of vegetable life.

As a practical promoter of husbandry, we cannot pass over M. de Fellenberg at Hofwyl, near Bern. On an estate of about 300 acres he put in practice nearly all that has been written by the most esteemed writers, taking Thaer as his text-book, and making himself acquainted with the best modern writers. He established an agricultural school for poor children, as a part of his great plan for general education, and his example has perhaps done more to promote good practical husbandry in his native country than all the works of the most eminent writers.

Belgium has always been foremost among agricultural countries. In 1600 the Flemings were considered the best husbandmen in Europe. There are no early writers on husbandry in this agricultural nation, but all travellers bear witness to their industry and to the perfection of their agriculture. They were probably the first in modern times who cultivated turnips in the field to feed cattle in winter; and who, in the north of Europe, kept their cattle in the stables all the year round and cut green food for them, as had been done from time immemorial in southern climates, on account of the excessive heat of the day and the annoyance of flies. The Belgians are now far advanced beyond most other nations of Europe in the application and economy of manure. They fully make up by incessant attention and indefatigable industry for the inferiority of their climate to that of Italy or Spain, and their land produces abundantly every necessary of life.

Husbandry of France.—France has always been looked upon as a country peculiarly agricultural. The climate, partaking of that of the north and the south, favours the cultivation of plants both of the warmer and of the colder regions. Charles Estienne is the first French writer on agricultural subjects whose works were published soon after the revival of letters; but, together with many useful maxims which he has copied from the ancient authors, he has repeated the most absurd superstitions. His works were collected and published in 1554, under the title of 'Prædium Rusticum;' and in 1565 he published his work called 'L'Agriculture et la Maison Rustique.' This work was reprinted, with additions, by his son-in-law, Jean Libeaut, in 1570. But the author, who is still considered as the father of French husbandry, is Olivier de Serres, a gentleman of fortune, proprietor of the seigneurie of Pradel, near Villeneuve de Berg, in Languedoc. He was a friend of Sully, the favourite minister of Henry IV.; and, at his request, about the year 1600, he wrote a work on husbandry, under the title of 'Théâtre d'Agriculture et Mesnage des Champs,' a work in which he shows a thorough knowledge of the great principles of husbandry. Subsequent writers on agriculture have been far too numerous to specify. Until recently, however, their influence was extremely small. But of late years a great amelioration has taken place, and the desire to promote practical improvements in husbandry appears to be steadily gaining ground, though the culture of a large part of the country is still in a very backward state. Agricultural schools and veterinary colleges have been multiplied; model farms on a very extensive scale have been established in many places by the Government, and by wealthy proprietors of land; extensive reclamations have been made of waste lands; better modes of cultivation are widely adopted, and the corn-produce has largely increased, partly in consequence of the abolition of the corn-laws in England, which has led the French farmer to look to the advantages offered by new foreign markets, but partly also as a result of the increased facilities offered by the construction of railways for reaching distant home markets. Much greater attention has also been paid of late years to improving the native breeds of stock; and a better class of agricultural implements is gradually coming into use.

HYACINTH, a favourite flower in gardens, is the *Hyacinthus orientalis* of botanists, a bulbous plant, found wild on the mountains of Persia, and remarkable both for its fragrance and the facility with which it varies in the colour, size, and construction of its flowers when raised from seed.

Few spring flowers are more worthy of cultivation than the hyacinth, whether we regard its varied shades of rich colour or the sweetness of its perfume. The Dutch gardeners have been celebrated for the high state of perfection to which they grow it, and for the monopoly they have secured in the sale of the bulbs, which have even acquired in the shops the familiar name of Dutch roots. The soil and climate of Holland seem to be peculiarly adapted to the plant, for however well imported roots may flower in England for the first season, they soon degenerate and become worthless. It is however probable that this arises from want of skill in our cultivation, rather than from anything unfavourable in our climate: for some gardeners have been successful in growing the same roots for several years in succession. Mr. Herbert says, "I produced for several years successively, at my villa in Surrey, where I had the advantage of the vicinity of the fine sand of Shirley Common, hyacinth flowers fully equal, if not superior, to those obtained from the best Dutch bulbs." As experience is in all respects the surest guide, the more nearly we approach the Dutch method of cultivation, the more likely we are to be successful. According to Mr. Herbert, the compost used at Haarlem is rotton cow-dung, rotten leaves, and fine sand. In making this compost the Dutch gardeners prefer the softer leaves of elm, lime, and birch, and reject those of oak, chesnut, walnut, beech, plane, &c., which do not rot so quickly. The cow-dung which they use is also of a peculiar quality, being collected in the winter when the cattle are stall-fed upon dry food, without any mixture of straw or other litter. The sand is procured in the neighbourhood of Haarlem, where the soil is a deposit of sea-sand upon a compact layer of hard undecayed timber, the remains of an ancient forest which has been overwhelmed by the sea. Having all these substances in a proper state, they are prepared in the following manner:—First, a layer of sand is placed, then one of dung, and then one of rotten leaves, each being eight or ten inches thick. These layers are repeated till the heap is six or seven feet high, a layer of dung being uppermost, sprinkled over with a little sand to prevent the too powerful action of the sun upon it. After the heap has lain for six months or more it is mixed, and thrown up afresh, in which state it remains some weeks, to settle, before it is carried into the flower beds. ('Hort. Trans.,' vol. iv., p. 163.)

The bed into which this compost is to be put must be taken out to the depth of three feet, its bottom made firm, and a few stones thrown into it in order to keep it dry. It must then be raised considerably above the level of the surrounding soil with the compost already prepared. The best season for planting is from October to the beginning of November, and the early sorts planted at this time will begin to show their flowers in the beginning of April.

Hyacinths are sometimes planted in rows or patches, but the most common and best way is to plant them in beds, because a greater mass of bloom is presented at once to the eye, and because it is easier to protect and shade them in this way. In planting them in beds a great part of the effect is produced by a judicious arrangement. The different colours are either blended together in the bed, or collected into masses. A mass of one colour is more pleasing to the eye than a mixture of several, and therefore each tint should be planted by itself in the bed; or if there are more beds than one, the first may be planted with white, the second with blue, the third with red varieties, and so on. The distance between each plant should be eight or nine inches.

As hyacinths are planted in autumn, and bloom early in the season, they never require any water. Against sharp frosts protection should be afforded by a covering of fern or leaves. In the spring the soil should be stirred lightly without damaging the bulbs; and a covering of matting supported on arched sticks should be used to protect them on frosty nights, which frequently occur. The bulbs will generally commence flowering in April and continue through May. As soon as the flowering is over, the more dry the ground can be kept, the better it is for the bulbs. When the leaves turn yellow and are withered, which will take place in about a month after the plants have gone out of flower, the bulbs must be carefully taken up and dried. The practice at Haarlem is this. "The leaves should be cut off, and each bulb laid on its side, covering it lightly with the compost, about two inches thick: in this state it should be left about a month, and then taken up in dry weather and exposed to the open air for some hours, but not to a powerful sun, which would be very injurious to it; it should after this be carefully examined, and all the decayed parts removed; afterwards it should be laid up in an airy storeroom." (Herbert, 'Hort. Trans.') Florists who have a valuable bed of hyacinths generally use an awning of some kind, to shade them from a bright sun, and protect them from heavy rains. This shade, of whatever material it is made, should be so constructed as to move up and down in favourable weather; in bright sunshine the bed may be exposed from four o'clock in the afternoon, or for a few hours in the morning. If the bed is not shaded, the colours very soon spoil, and will not bear a close examination.

Forcing of hyacinths is carried to a considerable extent, both in England and also on the Continent. When they are bloomed in this way, they are either used as ornaments to the greenhouse, or placed in the lobby or drawing-room, where the sweetness of their perfume renders them general favourites. The method of forcing them is the following:—Good Dutch bulbs, which are annually imported, are selected for this purpose. To save trouble, all which are intended to be forced may be potted at the same time, and placed in a cool greenhouse or frame; then as many as are intended to bloom at once must be placed in a gentle heat; when their flower-stems appear, others can be brought in which will succeed them, and by going on in this way a regular succession will be kept up. The pots into which they are put need not be large, but should be rather deep. The soil used for potting may either be the same as is recommended above, or a good loam will answer equally well. In potting, the bulbs must not be firmly pressed into the soil, but lie rather loose, and be only about half covered with it.

Hyacinths are frequently grown and flowered in water-glasses; for this purpose they are placed over water in October and November, and they flower in February. Sometimes before they are put into the glasses they are planted in pots, and when the roots have grown a little they are taken up and washed, and placed in the glasses, or they are placed in the glasses at first. The water must be frequently renewed, or it will soon become fetid and offensive. By far the most curious system of treating forced hyacinths is to invert them in large glass jars filled with water. This must be done when the flowers are nearly expanded; and by placing one above the glass, of the same size and colour with the inverted one, the latter presents an appearance of being the reflection of the former. The flowers retain their freshness much longer in the water than when exposed in the common way; but this circumstance, and the curious appearance presented, is all which can recommend the system; of course the fragrance of the hyacinth is in this way entirely lost. The principal difficulty that is experienced by those who force hyacinths in water in sitting rooms is to prevent their growing long, weak, and pale, so as to flower badly, and be in constant danger of upsetting. This is remedied by keeping them close to a window, where they can be constantly exposed to bright light all day long. It may also be added, that in order to secure their pushing out their roots before the leaves lengthen, they should always be kept in the dark for a fortnight or three weeks after they are first placed in the water-glasses, care being taken at that time that the water and the bulbs are not in contact. The moisture that rises into the air will be sufficient to induce the bulbs to put forth roots; and the total absence of light will prevent the leaves from being stimulated into growth.

Varieties are obtained from seed, and particular kinds are propagated by offsets. With the greatest care in gathering the seed, it is very uncertain whether or not the young plants raised from it will turn out well; however, the best sorts to gather seed from are those with strong upright stems, semi-double flowers, and brilliant and distinct colours. The seed must be well ripened, and then sown in good sandy soil, rather lighter than what is recommended for hyacinth compost. The young plants so obtained must not be disturbed or taken up until the end of the second, or, if they are weak, the third year; all that they require during that period is a little top dressing. They may then be taken up and planted in the bed, where they will require the same treatment as old roots; they will flower in the third spring, but it is better to destroy all the flowers of the first season, in order to strengthen the bulbs.

HYADES. [TAURUS.]

HYDANTOIC ACID ($C_8H_8N_4O_8$?). An acid product of the action of concentrated caustic potash upon allantöin. Its existence can scarcely be said to be established.

HYDA'TIDS (*ὑδατίς*, a vesicle, from *ὕδωρ*, water). This name has been applied to various cyst-like productions, which are sometimes found in the bodies of men and animals.

The term hydatid is of the most indefinite application, for under this common denomination are included objects of the most dissimilar nature. In the first place, the term comprehends several species of entozoa, or parasitic animals, which have a distinct independent vitality; secondly, the simple unattached cysts which are frequently met with; and lastly, what have been called false hydatids, which are vesicular bodies, either entirely or partially connected with the tissues by which they are surrounded.

Hartmann in 1686 ('Ephem. Nat. Curios.,' Ann. iv. dec. 2, obs. 73), and Tyson in 1691 ('Philos. Trans.,' No. 193), first clearly observed that many of the bodies, or cyst-like tumours, called hydatids, were distinct living beings, or parasitic animals. They arrived at this conclusion from observing that they had no connection with the organs in which they were found, that some of them distinctly moved when placed in warm water, and were also furnished with projecting processes or heads, having an orifice or mouth at their extremity. Morgagni and others have thought that some of the ancient medical writers, particularly Aretæus and Galen, were acquainted with the true nature of these bodies; but nothing of the kind is clearly stated in their writings, though they often mention the occurrence of hydatids.

The discovery of Hartmann and Tyson was taken little notice of before the time of Linnæus and Pallas, who pursued the investigation; since which time these beings have occupied the attention of many naturalists, among whom may be mentioned Hunter, Müller, Goeze, Cuvier, Laennec, and Rudolphi, who have all admitted the animal existence of the greater part, if not the whole of them. Pallas arranged all the cystic entozoa, except the common globular hydatid, or acephalocyst (which was only considered as a simple serous cyst before the time of Laennec), under the genus "Tænia," on account of the similarity of structure between their mouths and those of the tapeworm. In this classification he was followed by Goëze. Although these views were not generally adopted, it has been recently established by Küchenmeister Von Liebold and others that the various forms of cystic worms are but larval stages of Tænia. [ENTOZOA, NAT. HIST. DIV.]

Hydatids are found principally in the bodies of mammalia; rarely in those of the lower order of animals. They may occur in any part of the body, but are very seldom seen in the mucous cavities and passages, except when they have been discharged into them by the rupture of their containing cyst. This external sac, by which they are mostly surrounded, is generally attached to the tissue of the organ in which it is seated; it is frequently common to many hydatids, but each individual may have a distinct envelope, in the interior of which it floats, and to which it never contracts any adhesion. The fluid which fills the proper cyst of a hydatid is almost always colourless and limpid. The liquid of the common cyst in which they float may present various appearances: sometimes it is quite limpid; at others it may be coloured. When formed in the liver it is often yellow.

The principal forms of cystic entozoa, or true hydatids, recognised by Rudolphi and others are called Cysticercus, Cœnurus, and Echinococcus; to which may be added Acephalocystis. Several species of Cysticercus are enumerated, but the most common are C. tenuicollis, and C. cellulosus. The former (Tænia hydatigena, *Pallas*; Hydatis globosa, *Lamarck*) is met with frequently in the peritoneum and pleura of ruminating animals and pigs. It is often generated in the disease of sheep called the rot, where another entozoon, the "distoma," or fluke-worm, is met with in the ducts of the liver. The C. cellulosus (Tænia cellulosa et T. finna, *Gm.*; Hydatis finna, *Blum.*) is found generally lodged in the tissue of the muscles between the fibres; it occurs sometimes in man, but more frequently in animals, particularly in the hog, where it causes the disease called measles or leprosy. Of the genus Cœnurus (Hydatis polycephalus, *Zeder*), the species C. cerebralis (Tænia vesicularis, *Goëze*; T. cerebralis, *Gom.*; Polycephalus ovinus, *Zeder*) is found in the brain of sheep, oxen, and other ruminating animals. These hydatids occur in various parts of the brain of sheep, but most frequently in one of the lateral ventricles, where they occasion a kind of giddiness, in which the animal turns round and round in one direction; this affection is denominated by the German farmers "das Drehen," by the French "le Tournis," and in England the sheep are said to be "giddy," or to have the "staggers."

Sometimes the hydatid is situated in the fourth ventricle, when it is said to cause a variation in the affection, called in German "das Springen," from the animal springing up. Rudolphi says that he has seen the latter variety occur when one large hydatid has occupied the middle part of the brain. In the first case one-half of the body is rendered partially paralytic from the pressure of the hydatid on the side of the brain, and the opposite muscles by their action turn the body round towards the unaffected side. In the latter form of the disease, Rudolphi says that the equilibrium between the anterior and posterior muscles of the body is destroyed, which causes the animal to spring up. Sometimes two hydatids are found in the same ventricle, and occasionally as many as five or six have been met with. The internal surface of the ventricles is always smooth, and never contracts any adhesion to the cysts. This hydatid is sometimes found as large as a hen's egg; the walls of the bladder are very thin and fibrous; and may be seen clearly to contract. The little worm-like bodies attached to it are scarcely half a line in length, and have the power of retracting themselves within the cyst. These hydatids are most generally met with in yearling cattle and sheep, and their production, or that of the state of health which gives rise to them, seems owing principally to the effects of cold and damp, and watery pasturage, which also occasions the rot in sheep. The best treatment is removal to a dry and sheltered pasturage. In some cases sheep have been cured by the extraction of the hydatids by the operation of trepanning. Whenever any of these forms of hydatids are swallowed by man or the lower animals they proceed to develope themselves into tape-worms.

The hydatids belonging to the genus Echinococcus are commonly called granular hydatids, from the presence of numerous granules or minute particles, which are young hydatids which float in the fluid of the cyst or adhere to its walls. Two species of Echinococcus have been particularly described: one called E. hominis, has been met with in the brain and abdomen of man in a few instances; the other, E. veterinorum, occurs more frequently in the hog and other animals.

The Acephalocyst, or common globular hydatid, to which it is thought by some that the name of hydatid should be restricted, is a simple unattached vesicle, varying in size from a millet-seed to a child's head, filled with pellucid fluid, furnished with no kind of appendix or head, generally associated with numerous others, and contained in a common cyst, which is also filled with fluid. These bodies seem to possess a proper vitality, though dependent for existence on the body of the animal in which they live. They are probably undeveloped or abnormal forms of the more definite species.

Hydatids may be developed slowly, and occasion so little inconvenience, that persons in whom they have been discovered after death may not have suspected disease of the organ in which they existed during life. Occasionally they cause so much irritation that suppuration may take place either around or within the common sac, which may burst externally or into a serous mucous cavity. In either the first or last case the hydatids will be discharged, and the patient may recover; but if the cyst should communicate with a serous cavity, as the peritoneum or pleura, fatal inflammation will occur.

With respect to the treatment for the prevention or removal of hydatids, it is very imperfect. As they generally occur in a cachectic or disordered state of health, those remedies may be given which are most likely to remove that state and improve the general health. When a hydatid cyst is situated so near the surface of the body that it may be easily evacuated, without risk of effusion into the internal serous cavities, it may sometimes be punctured with propriety, which operation will cause obliteration of the sac. (WORMS.)

Pseudo or false hydatids are simple serous cysts or vesicles, either occurring singly or aggregated in clusters, but in both cases having a more or less close connection with the subjacent tissues, from which in fact they grow. The vesicles often found in the choroid plexuses belong to this class; also the cysts which contain the fluid in ovarian dropsy, which may grow to an enormous size. Lastly, one of the most common situations for these false hydatids is in the uterus, where they are described as "vesicles of a round or oval shape, with a narrow stalk to each, by which they adhere on the outside to one another." They may here increase in such numbers as to distend the uterus till it is too large to be contained in the pelvis, and rises into the abdomen. These cysts may be developed in many other situations, and contain fluids of various characters. For further information respecting them we must refer to a paper by Dr. Hodgkin, in 'Med. Chirur. Trans.,' vol. xv., p. 266.

HYDRA (constellation, ὕδρος in Ptolemy), the Water-snake, one of the old constellations. From the time of Aratus downwards it has always been a triple figure: a long snake, represented as trailing upon the ground, bears upon his back a cup (Crater), and nearer to his tail is seated a crow (Corvus). The mythological meaning is altogether unknown.

The great length of this constellation has caused it to be divided into four parts, which are designated as Hydra, Hydra et Crater, Hydra et Corvus, and Hydræ continuatio. The first contains the head and body up to about 10½ hours of right ascension, all near to and south of the bright star Regulus; the second contains the cup and the parts of the body adjacent; the third the crow, with the parts of the body adjacent; and the fourth (beginning at about 13 hours of right ascension) contains the tail. For the third part see CORVUS. In Flamsteed's catalogue Hydra and Hydræ continuatio are treated in all respects as two distinct constellations, with Corvus and Hydra et Crater intervening. Mr. Baily, in his new edition of the catalogue, has treated the two as one constellation, and numbered the stars accordingly, making 1, 2, &c., Hydræ continuationis to be 45, 46, &c., Hydræ.

HYDRA.

Character.	No. in Catalogue of Flamsteed.	No. in Catalogue of British Association.	Magnitude.
δ	4	2901	4
η	7	2945	4
ε	11	2971	4
ζ	16	3032	4
θ	22	3146	4
α	30	3228	2
ι	35	3308	4
κ	38	3311	4
λ	41	3478	4
μ	42	3568	4

HYDRA ET CRATER.

Character.	No in Catalogue of Flamsteed.	No. in Catalogue of British Association.	Magnitude.
α	7	3766	4
β	11	3826	4
ε	14	3881	4
γ	15	3883	4
θ	21	3943	4
ζ	27	3978	4

HYDRÆ CONTINUATIO.

Character.	No. in Catalogue of Flamsteed.	No. in Catalogue of British Association.	Magnitude.
γ	2	4450	3·5
π	5	4685	4

HYDRACIDS. Acids have been divided into oxacids and hydracids. In the former, an elementary body is combined with oxygen as the supposed acidifying principle; and in the latter, a substance, usually an elementary one, is united with hydrogen as the imaginary acidifying power.

The class of hydracids contains some which have been already treated of, as hydrobromic and hydrochloric acid; others remain to be described. With respect to the general properties of hydracids, it may be remarked that their acidity is in general very strongly marked; that they contain only one equivalent of hydrogen, and that when acted upon by metallic oxides they lose their hydrogen by its combining with the oxygen of the oxide, and the results are water and a haloid salt: thus, to put one of the most familiar cases, when hydrochloric acid is added to soda, or the oxide of sodium, the result is not a hydrochlorate of soda, but chloride of sodium and water. When, however, hydrochloric acid is united to bases which contain no oxygen, then real hydrochlorates are the result: thus, ammonia, which is a powerful alkaline base, combines with hydrochloric acid to form hydrochlorate of ammonia, or sal ammoniac. So, also, when the same acid unites with morphine, or any other oxygenous vegetable alkaloid, it is admitted that the resulting compound is a hydrochlorate of morphine, although this alkaline base and many other vegetable alkaloids do contain oxygen.

Most of the hydracids are gaseous, and are easily combined with water, forming solutions which possess the well known and strongly marked acid properties of sourness, acting upon carbonates, and reddening vegetable blue colours. They are all artificial products, except hydrochloric acid, which is sometimes disengaged from volcanoes.

The usual method of obtaining hydrochloric acid, as well as other hydracids, is that of treating a compound of the radical of the acid and a base with an oxacid and water, that generally used being sulphuric acid. Thus, as already mentioned, hydrochloric acid is obtained by acting upon chloride of sodium with hydrated sulphuric acid; the water suffers decomposition, and its oxygen combines with sodium to form soda, while its hydrogen unites with the chlorine, giving rise to hydrochloric acid; the soda combines with the sulphuric acid to form sulphate of soda. This may be taken as a type of the general action.

HYDRAMIDES. A class of organic compounds which may be described as *diamides*, derived from the action of ammonia upon the aldehydes. Hydrobenzamide may be taken as a type of these bodies; it is formed by acting with ammonia upon oil of bitter almonds:—

$$\underbrace{3\left.\begin{matrix}C_{14}H_5O_2\\ H\end{matrix}\right\}}_{\text{Oil of bitter almonds.}} + 2NH_3 = 6HO + \underbrace{N_2\left\{\begin{matrix}(C_{14}H_5)_2\\ (C_{14}H_5)H\\ H_2\end{matrix}\right.}_{\text{Hydrobenzamide.}}$$

The hydramides are neutral cystallisable substances, insoluble in water, soluble in alcohol, and volatile without decomposition.

The following is a list of the principal hydramides:—

Salhydramide	$C_{42}H_{18}N_2O_6$
Anishydramide	$C_{48}H_{24}N_2O_6$
Cinnhydramide	$C_{54}H_{24}N_2$
Furfuramide	$C_{30}H_{12}N_2O_6$

HYDRANZOTHIN. [CARBAMIC ACID.]

HYDRARGETHYL. [ORGANOMETALLIC BODIES.]

HYDRARGOBENZAMIDE. Synonymous with *Mercury benzamine.* [BENZOIC GROUP. *Benzamide.*]

HYDRATES are compounds of water: the term is however usually restricted to compounds which contain water in definite proportion, which water does not impart regularity of form, or in other words give crystals with the body with which it so unites. Thus when water is added to potash it may form with it either water of solution, water of crystallisation, or water which constitutes it a hydrate. If we take a solution of potash and evaporate it to a certain extent we obtain crystals of potash; heat these and the water of crystallisation is expelled, but no heat whatever is strong enough to expel the whole of the water, and the last remaining portions form with the potash a hydrate, which is a hard substance totally devoid of crystalline form. So also when water is added to lime, a portion dissolves; crystals however of water and lime are obtained with difficulty, but hydrate of lime is the well known dry powder called slacked lime.

It appears therefore, from the above statements, that water of solution has comparatively little affinity for the substance with which it is combined; water of crystallisation has more, but water which constitutes the body a hydrate has the greatest affinity of all.

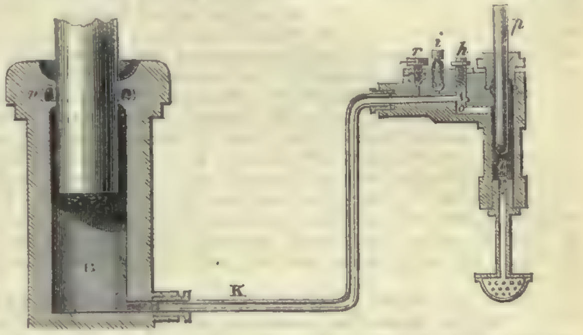
The water with which substances combine often imparts colour to them; thus sulphate of copper when deprived of water is nearly colourless, but when dissolved in water it becomes of a fine blue colour. Water of crystallisation produces the same effect. So also oxide of copper is of a black colour, but the hydrate of oxide of copper obtained by adding potash to a solution of copper is of a beautiful blue colour.

HYDRAULIC ENGINEERING. The branch of the arts of construction which is more especially connected with the resistance to the mechanical action of water, or with the use and application of that fluid to the various purposes of life, is usually known under the name of "hydraulic engineering." The objects comprised under this general title are not only numerous, but they are extremely complicated, and of the highest importance to nations where civilisation has been long and successfully developed. So complicated, indeed, are the objects the hydraulic engineer has to deal with, that there is hardly a branch of the applied sciences he may not from time to time be obliged to enlist in his service; and a mere enumeration of the various leading divisions of his art will suffice to prove the wide range of study it is necessary for him to cultivate. The divisions thus referred to have been, or will be, treated under their respective heads in this Cyclopædia.

The hydraulic engineer, in fact, has to execute the works required for the construction of BRIDGES, especially in so far as the foundations, coffer-dams, &c., are concerned; for BREAKWATERS; CANALS; DOCKS; DRAINAGE; EMBANKMENTS, in water; FOUNTAINS; IRRIGATION; LIGHTHOUSES; PIERS; SEA DEFENCES; SEWERAGE; WATER SUPPLY TO TOWNS; WATER-WHEELS; WELLS; or indeed for any purpose wherein it may be necessary to control or to use water in large bodies. There is little scope for the exercise of taste in these matters; they are nearly all within the domain of exact science; and no doubt their continually increasing importance in our modern societies has contributed to establish the distinction which now prevails between the pursuits of the architect and of the civil engineer; for the latter comprises amongst its varieties that of hydraulic engineering.

HYDRAULIC PRESS. This powerful engine was first suggested by Pascal, based upon the hydrostatic principle of *fluidity*, or the property of transmitting pressure equally and freely in every direction by which a liquid becomes in the truest sense of the term, a *machine.*

The hydraulic press consists essentially of a solid plunger, *p*, working through a water-tight collar in a small cylinder, at the bottom of which is a valve *c*, opening upwards, and conducting by a pipe into a cistern of water. In the side of the small cylinder is a channel, furnished with a valve *o*, opening upwards, and leading by a pipe K into a large cylinder B, in which is inserted a ram, passing through a water-tight collar *n*. The top of this ram is usually furnished with a plate forming the bottom bed of the press, moving in, and surrounded by, suitable frame-work. Now supposing both the cylinders *c* B with the connecting-pipe K to be filled with water, and the plunger *p* to be forced down from the top to the bottom of the small cylinder, the pressure thus produced will be transmitted by the water, through the pipe K to the ram in B, and according to the principle of fluidity [HYDROSTATICS] every square inch of the section of the ram will be pressed upwards with a force equal to the downward pressure on each square inch in the section of the plunger *p*. For example;—if the diameter of the section of the ram be twenty times that of the plunger, the upward pressure of the ram will be 400 times the downward pressure given to the plunger. Of course the pressure on the ram will be communicated to the bottom bed of the press, and any object placed upon it so as to be enclosed between it and the top of the frame will be compressed.



The extent to which the ram rises in the large cylinder must depend upon the relation of its diameter to that of the plunger. The plunger in descending its cylinder, displaces as much water as is equal to the volume of the portion that descends, and this water being driven into the large cylinder B, which is already quite full, the ram must rise through a height sufficient to afford room for the water which is thus forced into the cylinder, and the rise of the ram will clearly be less than the descent of the plunger, in the same proportion in which the sectional area of the plunger is less than that of the ram. If, as already supposed, the section of the ram be 400 times that of the plunger, the ram will rise through the 400th of an inch for every inch of descent made by the plunger. When the plunger is drawn up the cylinder preparatory to another stroke, the valve *c* opens, and admits a quantity of water, equal to the ascent of the plunger. And to prevent the ram from falling during this operation, the valve *o* is placed so as to intercept the water. When the plunger is again driven down, the pressure closes the valve *c* more firmly, and opens *o*. At *r* is a valve closed by a screw, communicating with a pipe that leads to the cistern in which the pump is immersed. When it is required to relieve the ram from pressure, and cause the bed-plate of the press to descend, this valve is opened, the ram descends, and the water from B is driven back through K, and through the pipe by which *r* leads into the cistern. When the press is used for very intense pressures, there is danger of bursting some parts of the machine, so that to prevent the pressure from exceeding a certain quantity, a safety valve *i* is provided. This valve opens outwards, and is closed by a weight attached to the longer arm of a lever, so that when the pressure transmitted to the ram exceeds a certain quantity, the valve opens and relieves the press.

As the pressure communicated to the ram acts with equal intensity on the interior of the large cylinder B, the water which communicates the pressure seeks to escape by the joint or collar through which the ram passes into B. To make such a joint or collar water-tight was the difficulty from the time of Pascal until that of Bramah, who in 1796 took out a patent for a water-tight collar, and thus made the hydraulic press an available engine. The collar is formed of a piece of strong leather in the form of a disc with a hole in the centre, and doubled down at the edges so as to form a ring, with the concavity downwards as shown in section *n*. As this collar exactly fits the ram, the water when pressed upwards enters the concave part, and presses it against the ram on one side and the surface of the cylinder on the other, so as to produce a perfectly water-tight joint, which has the merit of being more completely water-tight as the pressure is increased.

HYDRAULIC RAM. [HYDRODYNAMICS.]

HYDRAULICS. That branch of science which includes the phenomena of fluids in motion, and the modes of obtaining from them useful results. It is usually limited to what are called incompressible fluids or *liquids*, and may relate—1st, to the laws of the effluence of water from a reservoir; 2dly, to running-waters; 3rdly, to the use of water as a motive power; 4thly, to machines for raising water. For the theoretical part of the subject we refer to HYDRODYNAMICS. Its applications will be found under HYDRAULIC PRESS; PUMP; SYPHON; SCREW, ARCHIMEDEAN; WATER-WHEEL; WATER-MACHINE; TURBINE, &c.

HYDRIDES. Compounds containing hydrogen in combination either with an element or a compound radical, but not forming an integral part of a compound radical, are termed *hydrides*. Thus the bodies $(C_2H_3)H$ and AsH_3 are termed respectively hydride of methyl and terhydride of arsenic; but the compound radical methyl (C_2H_3) is not termed a hydride, because in its relations to other bodies it plays the part of a simple or elementary substance. [ORGANIC RADICALS.] The term hydride, as applied to the inorganic compounds of hydrogen, has almost become obsolete, other forms of nomenclature being almost exclusively used for such compounds. Thus we do not call the compounds of hydrogen with sulphur, nitrogen, and chlorine, hydrides, but sulphuretted hydrogen, ammonia, and hydrochloric acid. On the other hand, the term hydride has received very extensive application in naming organic compounds, amongst which we find hydrogen united, in the sense above described, both with positive and negative radicals.

Hydrides of Positive Radicals.—These bodies, isomeric with the positive radicals themselves, constitute an important class of hydrocarbons. They are met with amongst the products of the destructive distillation of organic substances, and can also be formed by two other reactions, namely:—

1st. By heating the potash salts of certain acids with excess of hydrate of potash. In this way hydride of phenyl [BENZOLE] is produced by heating benzoate of potash with hydrate of potash:

$$\underbrace{\left.\begin{matrix}C_{14}H_5O_2\\K\end{matrix}\right\}O_2}_{\text{Benzoate of potash.}} + \underbrace{\left.\begin{matrix}K\\H\end{matrix}\right\}O_2}_{\text{Hydrate of potash.}} = \underbrace{\left.\begin{matrix}C_{12}H_5\\H\end{matrix}\right\}}_{\text{Benzole.}} + 2KOCO_2$$

2nd. The hydrides of the positive radicals are formed by the action of water upon the zinc compounds of the positive radicals, thus:—

$$\underbrace{\left.\begin{matrix}C_2H_3\\Zn\end{matrix}\right\}}_{\text{Zincmethyl.}} + HO = ZnO + \underbrace{\left.\begin{matrix}C_2H_3\\H\end{matrix}\right\}}_{\text{Hydride of methyl.}}$$

The following are the principal known hydrides of positive radicals:—

I. IN THE ETHYL FAMILY.

	Formulæ
Hydride of methyl, or light carburetted hydrogen .	$\left.\begin{matrix}C_2H_3\\H\end{matrix}\right\}$
Hydride of ethyl	$\left.\begin{matrix}C_4H_5\\H\end{matrix}\right\}$
Hydride of amyl	$\left.\begin{matrix}C_{10}H_{11}\\H\end{matrix}\right\}$

II. IN THE PHENYL FAMILY.

Hydride of phenyl, or benzole	$\left.\begin{matrix}C_{12}H_5\\H\end{matrix}\right\}$
Hydride of toluenyl, or toluol	$\left.\begin{matrix}C_{14}H_7\\H\end{matrix}\right\}$
Hydride of cumenyl, or cumol	$\left.\begin{matrix}C_{18}H_{11}\\H\end{matrix}\right\}$
Hydride of cymenyl, or cymol	$\left.\begin{matrix}C_{20}H_{13}\\H\end{matrix}\right\}$

Some hydrides of positive radicals are gases, others liquids or solids. They are remarkable for their stability and resistance to chemical agents. Paraffin probably belongs to this class of organic compounds.

Hydrides of Negative Radicals.—These bodies, commonly termed *aldehydes* (from *alcool dehydrogenatum*), are intermediate between the alcohols and the derived acids, thus:—

$$\underbrace{\left.\begin{matrix}C_4H_5\\H\end{matrix}\right\}O_2}_{\text{Alcohol.}} \qquad \underbrace{\left.\begin{matrix}C_4H_3O_2\\H\end{matrix}\right\}}_{\text{Aldehyde.}} \qquad \underbrace{\left.\begin{matrix}C_4H_3O_2\\H\end{matrix}\right\}O_2}_{\text{Acetic acid.}}$$

They are generally formed by the action of oxidising agents upon the alcohols; œnanthylic aldehyde is obtained by the dry distillation of castor oil, whilst a few others are met with ready formed in essential oils. The hydrides of the negative radicals are as remarkable for their instability as those of the positive are for the opposite property. They rapidly attract oxygen from the air and pass into the corresponding acids; thus, vinic aldehyde passes into acetic acid:—

$$\underbrace{\left.\begin{matrix}C_4H_3O_2\\H\end{matrix}\right\}}_{\text{Aldehyde.}} + O_2 = \underbrace{\left.\begin{matrix}C_4H_3O_2\\H\end{matrix}\right\}O_2}_{\text{Acetic acid.}}$$

They are also very prone to change into isomeric compounds. With the bisulphates of the alkalies they form crystalline compounds. They are powerful reducing agents, throwing down metallic silver when heated with the solution of the ammonio-nitrate of that metal.

The following are some of the chief hydrides of negative radicals:—

I. IN THE ACETIC FAMILY.

	Formulæ.
Hydride of ethyl, or aldehyde	$\left.\begin{matrix}C_4H_3O_2\\H\end{matrix}\right\}$
Hydride of propionyl	$\left.\begin{matrix}C_6H_5O_2\\H\end{matrix}\right\}$
Hydride of butyryl	$\left.\begin{matrix}C_8H_7O_2\\H\end{matrix}\right\}$
Hydride of valeryl	$\left.\begin{matrix}C_{10}H_9O_2\\H\end{matrix}\right\}$
Hydride of œnanthyl	$\left.\begin{matrix}C_{14}H_{13}O_2\\H\end{matrix}\right\}$
Hydride of palmityl	$\left.\begin{matrix}C_{32}H_{31}O_2\\H\end{matrix}\right\}$

II. IN THE ACRYLIC FAMILY.

Hydride of acryl, or acrolein	$\left.\begin{matrix}C_6H_3O_2\\H\end{matrix}\right\}$

III. IN THE BENZOIC FAMILY.

Hydride of benzoyl, or oil of bitter almonds . .	$\left.\begin{matrix}C_{14}H_5O_2\\H\end{matrix}\right\}$
Hydride of cumyl, or cuminol	$\left.\begin{matrix}C_{20}H_{11}O_2\\H\end{matrix}\right\}$

Descriptions of the positive and negative hydrides will be found under the respective radicals.

HYDRINDIN. [INDIGO.]

HYDRIODIC ACID. [IODINE.]

HYDRO. A chemical prefix, see CHEMICAL NOMENCLATURE. *Nomenclature of Acids.*

HYDROBENZAMIDE. [BENZOLONE; HYDRAMIDES.]

HYDROBENZILE $(C_{28}H_{12}O_2)$. A product of the action of sulphide of ammonium upon benzile. It is a colourless crystalline body, soluble in alcohol and ether, insoluble in water, fusing at 117° Fahr., and distilling unchanged. It possesses an odour like that of oil of bitter almonds. [BENZOIC GROUP.]

HYDROBENZOINAMIDE. [BENZOINAMIDE.]

HYDROBROMIC ACID. [BROMINE.]

HYDROCARBONS. This name is applied to a very numerous class of chemical compounds consisting of carbon and hydrogen. The chief hydrocarbons whose constitution is well known are the monatomic and biatomic radicals, the double radicals, and the hydrides of the monatomic radicals. In addition to these, however, a host of other similar compounds of less certain constitution are met with amongst the products of the destructive distillation of animal and vegetable substances; the illuminating effect of coal gas, for instance, is due exclusively to certain gaseous and volatile hydrocarbons, whilst coal tar and wood tar are rich in the same class of compounds.

A large number of hydrocarbons, of which olefiant gas may be taken as a type, contain an equal number of equivalents of the two elements, their composition being expressed by the general formula CnHn, n representing an even number, as 2, 4, 6, &c. Two other families contain an excess of hydrogen; these are represented respectively by the formulæ CnHn + 1 and CnHn + 2. Another class, to which benzole belongs, has the composition CnHn—6, whilst naphthalin seems to represent a similar family of the form CnHn—12. Other hydrocarbons, of the form CnHn—1 and CnHn—7, appear also to exist, although they are less extensively known than the other families. As regards their state of aggregation, some hydrocarbons are gaseous, as olefiant gas, others liquid, as benzole, and others solid, as naphthalin and paraffin. The hydrocarbons of the form CnHn and CnHn—12 are readily acted upon by chlorine, bromine, and other agents; whilst the families CnHn + 1 and CnHn + 2 are remarkable for their great indifference towards chemical reagents, a characteristic which has given to one of them the name paraffin. [ORGANIC RADICALS; HYDRIDES.]

HYDROCELE (from ὕδωρ, water, and κήλη, a tumour) is a collection of watery fluid in the tunica vaginalis testis. It is characterised by the formation of a tumour, which enlarges gradually without heat or pain, has a pyriform shape, is firm and elastic, often appears transparent when a light is placed behind it, and does not, like a hernia, diminish in size when the body is in a recumbent posture, nor communicate any impulse when the patient coughs. In most cases the fluid collects without any distinct cause; but in some it follows rapidly after an injury of the part. The quantity of fluid which accumulates varies from a few ounces to four or six pints. The disease often occurs in those who are otherwise in perfect health, and in persons of all ages; it may be seated on one or both sides of the body. The treatment consists, 1st, in the evacuation of the fluid by tapping; and, 2nd, in preventing it from accumulating again by exciting such active inflammation of the opposite surfaces of the tunica vaginalis as may produce their adhesion and the obliteration of the cavity. The latter purpose is generally fulfilled by the injection of some stimulant fluid, or the introduction of a foreign body into the cavity.

HYDROCEPHALUS (from ὕδωρ, water, and κεφαλή, head), water in the head, is a name applied to two diseases nearly peculiar to infancy and childhood, which are distinguished as the acute and the chronic. These diseases differ entirely in their nature. Acute hydrocephalus is a disease rapid in its course and essentially inflammatory in its nature, and of which the effusion of fluid in the head is but one, and that not a constant effect or concomitant. To constitute chronic hydrocephalus (an affection which may last many years), the only essential condition is the accumulation of a watery fluid within the skull, which may or may not be caused by or attended with inflammatory action.

1. *Acute hydrocephalus* is a most frequent and fatal disease of the early stages of life. It occurs most commonly between the first and the eighth year, and corresponds in a great measure to the inflammation of the brain (phrenitis and arachnitis) of later years.

The rapidity of the disease when once formed, and its frequently fatal termination, render it a matter of the greatest importance to detect its first or premonitory symptoms. But these, which it frequently falls to the lot of the parents and friends only to observe, are unfortunately seldom so marked as to be thought to demand medical aid, and are indeed with great difficulty distinguished from the symptoms of other affections of far less formidable nature.

The child is perhaps liable to momentary giddiness while moving quickly, is fretful and nervous, and its rest is disturbed; it loses its appetite, its bowels are costive, and the motions offensive. The eyes become heavy and very sensible to light, the face is pale, and the features devoid of animation. There is more and more indisposition to motion; the little patient complains of heaviness of the head, and loses its strength; its gait is unsteady. Of the above symptoms, those referrible to the bowels are frequently most prominent: purgative medicine is given, and sometimes relieves the symptoms for a time. The child may remain in this state for several days or weeks without anything more than heaviness or slight pain in the head being complained of, and without any fever; but when the symptoms persist after purgative medicine has acted, they should be looked upon with apprehension; and if there be no known cause, such as the presence of worms in the intestines or the eruption of a tooth, to account for them, they should be closely attended to from the commencement.

The symptoms more surely indicative of the disease are more intense pain in the head, to which the child constantly carries its hand; intolerance of light, sound, and motion; squinting; heat of the head; knitting of the brows; disturbed sleep, with grinding of the teeth, the child frequently waking with a scream; the pulse being at the same time slow and irregular, and not quick as in fever from worms or teething. The appetite is lost, the evacuations from the bowels are unhealthy, and vomiting ensues. The abdomen, if previously distended, now falls in and becomes quite flat. Stupor, interrupted by screams, follows. After these symptoms have continued for some hours or days, there will sometimes be a temporary recovery of sense; the child will see, hear, and know its friends, and will take its food; but this promising state is soon interrupted by convulsions of the whole body, or of one side, paralysis of one side, return of the squinting, complete loss of sight and hearing, and inability to swallow; still greater emaciation ensues, the breathing becomes irregular, the extremities cold, and death follows.

This is the more usual course of the disease; it then generally lasts several days or even weeks. But it in some instances comes on suddenly, and proves fatal in a few hours. In other cases the symptoms are less severe and more prolonged; and chronic hydrocephalus gradually developes itself.

The appearances which are found in the brain after death are congestion of the blood-vessels, effusion of serum mixed with lymph in very variable quantity between the membranes at the base of the brain or in its cavities, and softening of the substance of the brain itself, particularly of those parts of it which form the floor of its cavities or ventricles. Sometimes there is merely effusion of clear serum, sometimes no effusion, but merely softening of the cerebral substance.

Causes.—Children of scrofulous diathesis, or of irritable temperament, and those of precocious intellect, with a large head, are most subject to this disease. It may in fact be essentially regarded as a disease of scrofulous origin. Scrofulous children should be as much as possible guarded from agencies likely to excite increased flow of blood to the brain, such as cold or external violence to the head, the influence of the sun, the suppression of eruptions of the skin, and particularly of the scalp, the use of narcotic remedies, as opium, too great excitement of the mind, and the early exercise of the intellectual powers.

The *treatment* must vary in the different stages of the disease, but will generally consist in endeavouring to subdue inflammatory action, in removing any causes which may, directly or indirectly by sympathy, keep up irritation of the brain; and lastly, in the latter stages, in supporting the strength of the system.

In order to subdue the disease in the inflammatory stage leeches should be applied to the temples, and some have even recommended the abstraction of blood from the jugular vein. Active purgatives should be administered, and the circulation should be controlled. Mercurials were formerly recommended, but the fact of the origin of this disease in a scrofulous habit has led to a considerable modification of this practice. When the active symptoms have been subdued, an alterative course, consisting of iodide of potassium with slight tonics, have been found most beneficial.

Spurious hydrocephalus.—There is a form of disease to which children are liable, and which has been called spurious hydrocephalus, which, with symptoms closely resembling the above disease, comes on, nevertheless, in an opposite state of the system. It arises from depletion, loss of blood, or active medicines. In these cases active remedies speedily destroy the life of the child. Dr. Watson states that as these cases are very difficult to distinguish from those of acute hydrocephalus, he is guided by the state of the unclosed fontanelle. If the unclosed fontanelle be convex and prominent, he regards it as indicative of the acute form of the disease; but if it be depressed and concave, he prescribes a better diet, ammonia, brandy, and arrow-root, instead of depletants.

2. *Chronic hydrocephalus.*—The disease to which this name is applied is correctly denominated water in the head, being always accompanied with a considerable collection of watery fluid in the cavity of the head, sometimes within the membranes of the brain only and exterior to the organ itself, but more frequently in the ventricles or cavities of the cerebral hemispheres, which are then distended to the form of a sac. The quantity of fluid is sometimes so great as to cause an increased size of the skull, amounting to great deformity; the face, remaining of its natural size, appears disproportionately small. The disease generally arises before or very soon after birth; and the cranial bones not being completely ossified at the time of its commencement, they become separated to a distance from each other, and the sutures remain open for a long period. When the disease comes on after birth its early progress is very insidious.

Symptoms.—The intellectual faculties are always deranged, and the senses generally more or less disordered; there is usually impaired vision or blindness, with squinting; speech is imperfect; the voluntary power over the limbs is partially lost, giving rise to an unsteady gait, as a frequent symptom. The digestive functions, respiration, and circulation, are in most cases unaffected until near the termination of the disease. The unfortunate patient is sometimes the subject of occasional epileptic fits. In the latter stages of the disease the loss of intellect and of the power of motion increases, till at last complete coma and paralysis ensue.

The duration of the disease is extremely various. It may terminate fatally even before birth, or the child may live for many months or years. A man named Cardinal, the subject of water in the head, died a few years since at Guy's Hospital, aged thirty-two years: and a woman is mentioned by Gall and Spurzheim as having lived to the age of fifty-four years, though after death four pints of fluid were found in her head.

The amount of fluid accumulated in the brain or its membranes is as various as the duration of the affection. It may not exceed half a pint or a pint, or it may reach the quantity of several pints. In the patient Cardinal, ten pints of fluid were contained in the head. Cases are recorded in which as many quarts have been found.

Causes.—The children of scrofulous parents, and those of a rickety diathesis, are most prone to chronic hydrocephalus. Any causes acting on the mother so as to interfere with the proper nutrition of the fœtus may produce it. Sometimes several children of the same parent are similarly affected from birth. Chronic hydrocephalus may be left as a consequence of the acute disease.

Treatment.—In the majority of cases medical treatment is quite useless, except in the early stage of the disease, and when it has come on subsequently to birth. If there are symptoms of subacute inflammation existing, the means calculated to subdue this are used with benefit. The next great object to be effected is to remove the accumulated fluid. This may be attempted by internal remedies supposed to accelerate absorption, or it may be effected by puncturing the head. The latter operation has been performed at different times by many surgeons, and in numerous instances with success.

HYDROCHLORIC ACID. [CHLORINE; *Hydrochloric acid.*]

HYDROCHRYSAMIDE. [CHRYSAMMIC ACID.]

HYDROCYANALDIN ($C_{18}H_{12}N_4$). A product of the action of hydrocyanic and hydrochloric acids upon aldehyde-ammonia. When these bodies are gently heated together they form alanin [ALANIN], but without heat the reaction produces hydrocyanaldin:

$$3\underbrace{\left.\begin{matrix} C_4H_3O_2 \\ NH_4 \end{matrix}\right\}}_{\text{Aldehyde ammonia.}} + \underbrace{3C_2NH}_{\text{Hydrocyanic acid.}} + 2HCl = \underbrace{C_{18}H_{12}N_4}_{\text{Hydrocyanaldin.}} + 2NH_4Cl + 6HO$$

Hydrocyanaldin is a neutral, insipid, and colourless crystalline substance. Heated with potash, it disengages ammonia, whilst the solution becomes brown from the separation of resin of aldehyde.

HYDROCYAN-HARMALINE ($C_{26}H_{14}N_2O_2, C_2NH$). An organic base composed of harmaline and hydrocyanic acid. It is best obtained by dissolving harmaline in a weak boiling solution of hydrocyanic acid, and then filtering whilst hot. As the liquor cools, the base crystallises out in thin rhomboidal tables, soluble in water and alcohol. It forms very instable salts with acids, which readily decompose into salts of harmaline and free hydrocyanic acid.

When nitroharmaline is treated in the same way, it yields another crystalline base, *hydrocyano-nitroharmaline*, having the formula $(C_{20}H_{15}(NO_4)N_2O_2, C_2NH)$. [HARMALINE.]

HYDROCYANIC ACID. [CYANOGEN.]

HYDROCYANO-NITROHARMALINE. [HYDROCYAN-HARMALINE.]

HYDRODYNAMICS. Under this word are usually comprehended the conditions of equilibrium and of motion in non-elastic fluids, with the resistances which they oppose to bodies moving in them. When a fluid is in a state of rest, the investigation of its equilibrium and that of bodies immersed in it, with the investigation of the pressure exerted by the fluid on bodies immersed in it, or containing it, form the subjects of hydrostatics. Hydrodynamics, which was formerly included under the term *hydraulics*, is concerned chiefly in investigating by mathematical reasoning, or in showing from observation and experiment, the laws relating to the discharge of fluids through orifices and tubes in vessels or reservoirs, and to their motions in canals or rivers.

Concerning the laws of the motions of fluids as they were known to the ancients, little can be said; the only notice of this branch of science, even in the time of the Roman empire, is contained in the treatise 'De Aquæductibus,' which was composed by Frontinus, in the reign of Nerva or Trajan. This writer shows that the quantity of water issuing from an orifice depends on its magnitude, and on the height of the water in the reservoir above the orifice; and he states that a short tube applied to an orifice permitted a greater discharge of fluid than could be obtained from a simple perforation of equal diameter. He appears, however, to be unacquainted with the manner of determining the velocity when the height or *head* of the water is given; and it is not certain that this elementary proposition was solved till the time of Torricellius, who, in 1643, assigned the law correctly, for that case only, however, in which the aperture is very small compared with the height of the water in the vessel or reservoir.

It appears that, even at the end of the 16th century, the cause of the ascent of water in pumps was little known; for Galileo, having occasion to make some observations on the phenomenon, could give no better reason for it than that it was caused by an attraction which he supposed the piston exercised on the water; and not being able to make the column of water follow the piston when the latter was about 34 feet above the surface of that in the well, he attempted to explain the circumstance by saying that the weight of the column was then so great as to overcome the attraction of the piston. We are indebted to Torricellius for the discovery that the rise of the water is owing to the pressure of the atmosphere on that which, in the well, surrounded the pump, and which is thus forced into the barrel, in consequence of the removal of the internal air, till the weight of the column raised is in equilibrio with that pressure. [BAROMETER.]

Castelli, a disciple of Galileo, in his treatise 'Della Mesura dell' Acque Correnti' (1628), appears to have been the first who applied himself to the investigation of the motion of fluids in rivers; and, together with several other circumstances relating to such motion, he shows that when the bed of a canal whose transverse section is variable has taken a permanent form, the velocities at different sections are inversely proportional to the areas of those sections. This branch of the science was subsequently much cultivated in Italy, probably on account of its connection with the important operations then in progress for improving the navigation of the Po and draining the marshes in the northern part of that country. The Marquis Poleni wrote, in 1695, a work entitled 'De Motu Aquæ mixto;' and, in 1718, another concerning the flow of water through orifices and short tubes; and numerous works containing the results of their investigations, and experiments relating to the same subjects, have been made public by other distinguished Italian mathematicians.

The 'Principia' of Newton contains (lib. ii., sect. 7) a series of propositions concerning the motions of fluids. In the first edition (1687) the law of the velocity of water flowing from vessels, being founded on experiments made with orifices of considerable magnitude, appeared to differ from that which had been observed by Torricellius; but the discovery of the *vena contracta*, which was introduced in the second edition (1713), explained the reason of the apparent discrepancy. Newton also investigated the resistance of fluids to bodies moving in them; and it may be said that his theory forms the groundwork of all our knowledge concerning that subject.

Daniel Bernoulli (in 1738) was the first who applied the higher branches of mathematical analysis in the investigation of general equations relating to the problems of hydrodynamics; and though objections were made to the principle which he adopted, yet the independent investigations of succeeding mathematicians have only confirmed the results at which the former had arrived. The subject was taken up in 1744 by D'Alembert, who, assuming that the motion of each horizontal lamina of fluid in a vessel, during its descent in consequence of the efflux from the orifice, is compounded of two motions, namely, that which it had at the moment preceding any given time, and that which is subsequently lost, arrived at equations containing, in the *implicit* form, all the circumstances attending the efflux at the orifice. And, subsequently, he investigated corresponding equations from the assumption, first, that a rectangular canal supposed to exist in a fluid mass which is in equilibrio is itself in equilibrio; and secondly, that a molecule of fluid supposed to be incompressible retains the same volume under a different form in passing from one place to another.

The researches of Euler, La Grange, La Place, and other Continental mathematicians have, since, contributed greatly to establish the principles of the science on an analytical basis. The laws of the motions of fluids in canals and rivers were, with every possible precaution to ensure accuracy, determined experimentally by the Abbé Bossut in 1771, and by the Chevalier Du Buat in 1786.

In investigating the circumstances attending the discharge of fluids through orifices it is usual, according to the theory of *Parallelism of Strata*, to suppose the fluid to be divided into an infinite number of indefinitely thin laminæ perpendicular to the axis A B (*fig.* 1) of the vessel in which it is contained, and that in the descent of the fluid these laminæ preserve their parallelism till they come near the orifice, when they assume the shape of a funnel, about which the fluid is stagnant. In the process immediately following, let the vessel be cylindrical or prismatical, in a vertical position, and have an orifice at B. Now if $pp'q'q$ be such a lamina, its distance from A being expressed by x, and its area (perpendicularly to the axis) by a, we shall have $a.dx$ for the volume of the lamina; also D being its density, we have $a\,\mathrm{D}\,dx$ for its mass. The force with which this lamina tends downwards is its gravity, and the resistance experienced in the descent is the excess of the pressure from below upwards over the downward pressure of that above the plate. If g represent the force of gravity, then $\mathrm{D}\,ag\,dx$ is equal to the action of gravity on the plate in its descent, that is, the *weight* of such a lamina.

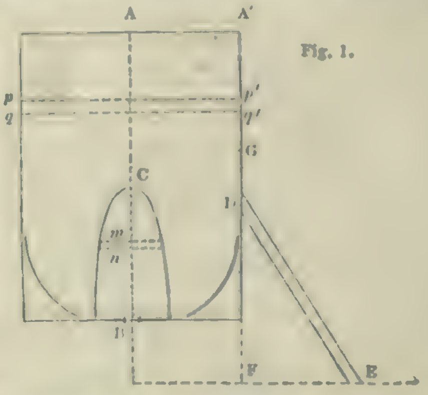


Fig. 1.

Let p represent the pressure exerted downwards by the water above, against any elementary portion of the lamina: then, the pressure of the water at the upper and under surfaces of the lamina being proportional to the depth of those surfaces below A, $p+dp$ acting upwards may represent that of the water below: hence the resistance of the water below the lamina will be $a\,dp$; and therefore the motive force by which the lamina descends will be $ga\,\mathrm{D}\,dx - a\,dp$. This being divided by the mass of the latter will (by mechanics) give $\frac{g\,a\,\mathrm{D}\,dx - a\,dp}{a\,\mathrm{D}\,dx}$ or $\frac{g\,\mathrm{D}\,dx - dp}{\mathrm{D}\,dx}$ for the accelerative force of descent. But in variable motions the accelerative force is expressed by $\frac{dv}{dt}$ (v being the velocity and t the time); or, since $v=\frac{dx}{dt}$, the accelerative force is expressed by $\frac{d^2x}{dt^2}$: therefore $\frac{d^2x}{dt^2} = \frac{g\,\mathrm{D}\,dx - dp}{\mathrm{D}\,dx}$.

But the quantity of water flowing through the orifice at B in any given time being evidently equal to that which would pass through the space $pp'q'q$, whose depth is dx, in the same time; if v be the velocity of a particle in its descent through the depth pq or dx, and u that of a particle in the orifice, we shall have, in the element dt of time (a' being the area of the orifice), $a'u\,dt = a\,dx$, or $dx = \frac{a'u\,dt}{a}$; whence, considering a, a' and dt as constant, we get $d^2x = \frac{a'\,du\,dt}{a}$: which, being substituted in the above equation for $\frac{d^2x}{dt^2}$, we obtain $\frac{g\,\mathrm{D}\,dx - dp}{\mathrm{D}\,dx}\,dt^2 = \frac{a'\,du\,dt}{a}$, or $ag\,\mathrm{D}\,dx - a\,dp = \mathrm{D}\,a'\,du\,\frac{dx}{dt}$.

But the equation $a'u\,dt = a\,dx$ gives $\frac{dx}{dt} = \frac{a'u}{a}$; therefore the last equation becomes $g\,\mathrm{D}\,dx - dp = \frac{\mathrm{D}\,a'^2u\,du}{a^2}$, whose integral is $g\,\mathrm{D}\,x - p = \frac{\mathrm{D}\,a'^2u^2}{2a^2}$ + constant; whence

$$p = g\,\mathrm{D}\,x - \tfrac{1}{2}\,\frac{a'^2}{a^2}\,u^2\,\mathrm{D} + \text{constant}.$$

Let $x = h$ (= A B) and $a = a'$, then

$$p = g\,\mathrm{D}\,h - \tfrac{1}{2}\,\mathrm{D}\,u^2 + \text{constant};$$

and subtracting this equation from the preceding, we have

$$o = g x - \tfrac{1}{2} \frac{a'^2}{a^2} u^2 - gh + \tfrac{1}{2} u^2.$$

This expresses, according to the theory of *fluid threads*, the relation between the velocity u and the difference between the weights of two filaments of the fluid having unity for the base of each, and whose heights are h and x. When $x = o$, the equation becomes $o = -\tfrac{1}{2} \frac{a'^2}{a^2} u^2 - gh + \tfrac{1}{2} u^2$; or considering the orifice as infinitely small so that a' and the whole first term of the second member vanishes, we have $o = -gh + \tfrac{1}{2} u^2$; whence $u = \sqrt{2gh}$.

Now gh expresses the weight of a prism of fluid having unity for the area of its base and whose height is h, h being the vertical distance of the surface of the fluid from the centre of gravity of the orifice, which is called the "*charge of water*" on the orifice; and this is the pressure of the fluid against a small orifice at the bottom of the vessel: but, while the height h is the same, the pressure is the same whatever be the position or inclination of the orifice: therefore $\sqrt{2gh}$ will express the velocity at the same depth, whether the orifice be at the bottom or side of the vessel. By the theory of dynamics this is equal to the velocity acquired by a body in descending by gravity through a height h, equal to that of the column of fluid, the orifice being infinitely small.

It may be concluded from the above theorem, that the velocity of a fluid spouting upwards through an orifice in a vessel would cause it to ascend to the level of the upper surface of that in the vessel, if the resistance of the air and of friction were abstracted. Hence we see that if Q = waste of water per second, m = a constant coefficient, d the surface of the orifice; then $Q = mud = md\sqrt{2gh}$. Now m is found to be always $= \cdot 62$ in orifices with thin walls; hence $Q = 4 \cdot 98 \sqrt{h}$. In orifices with a cylindrical spout, 3 or 4 times the size of the orifice, we shall have $u = \cdot 82 \sqrt{2gh}$, and the *waste* $= Q = \cdot 82 d \sqrt{2gh} = 6 \cdot 58 \sqrt{2h}$.

It follows, also, that the velocities of spouting fluids, at different depths below the upper surface, are proportional to the square roots of the depths; that the quantities of fluids discharged in equal times at different depths in the vessel, *the latter being constantly full*, are to one another in a ratio compounded of the areas of the orifices and the square roots of the depths; and the quantity of water which would be discharged in a given time t, through an orifice a in a vessel kept constantly full at the height h, is expressed by $a' t \sqrt{2gh}$.

The velocity u or $\sqrt{2gh}$ expresses the length of a cylinder of water which would flow through the orifice in one second; consequently the time of discharging, from a cylindrical or prismatical vessel, the area of whose base is a and whose height is h, a quantity of water equal to that which the vessel will contain, the latter being however kept full during all the time that the water is flowing, will be found by making ah equal to $a't\sqrt{2gh}$; whence t (the time required) $= \frac{a}{a'} \sqrt{\frac{h}{2g}}$. The value of g is 32·19 feet, or 386·28 inches; and in these values of u and t it is evident that the areas and height must be of the same denomination as g.

When a vessel is *suffered to discharge itself gradually*, the velocity of the effluent water diminishes continually. Now if x be the depth to which the water has descended at the end of the time t, h being the whole height when the vessel is full, $h - x$ will be the height of the fluid at that time; and we shall have $\sqrt{2g(h - x)}$ for the velocity in the orifice. This may be supposed constant during the time dt, and then the quantity of fluid discharged in that element of time would be equal to $a' dt \sqrt{2g(h - x)}$. In the time of this discharge the upper surface of the fluid will descend through the depth dx; therefore the area of the upper surface being a, we have $a\,dx = a'\,dt \sqrt{2g(h - x)}$, and $dt = \frac{a\,dx}{a'\sqrt{2g(h - x)}}$. If the vessel is an upright cylinder or prism, a is constant, and the integral of the expression is $t = -\frac{2a}{a'\sqrt{2g}} \sqrt{h - x}$ + constant. But, when $x = o$, we have $t = o$; therefore $o = -\frac{2a}{a'\sqrt{2g}} \sqrt{h}$ + constant; whence $t = \frac{2a}{a'\sqrt{2g}} (\sqrt{h} - \sqrt{h - x})$; which, when $x = h$, becomes $t = \frac{a}{a'} \sqrt{\frac{2h}{g}}$; and comparing this with the time in which an equal quantity would run off, *the vessel being kept full*, it will be found to be *double* the latter.

Next, if it were required to determine the quantity of water which would flow through an orifice of finite magnitude when cut in the vertical side of a vessel which is kept constantly full, it must be observed that the velocity of the effluent fluid at different points in the depth of the orifice varies as the square root of the distance of the point from the upper surface. Now let AB ($= h$) be the vertical height of the water in a vessel in one side of which is formed the orifice whose axis is CB, and imagine the horizontal ordinates at m and n to be drawn indefinitely near each other. Let $CB = h'$, $Cm = x$, the ordinate at $m = y$, $mn = dx$: then ydx is equal to the elementary area of the orifice; and the water flowing through the area in the time t, being that which is due to the height Am, is expressed by $t\,y\,dx \sqrt{2g(h' + x)}$; which, being integrated between $x = o$ and $x = h - h'$, would give the quantity of water discharged through the whole orifice in the time t. If the orifice were rectangular, y would be constant: suppose it $= b$; then the indefinite integral would be $b\,t\sqrt{2g} \int (h' + x)^{\frac{1}{2}}\,dx$, or $\frac{2}{3} b\,t \sqrt{2g}\,(h' + x)^{\frac{3}{2}}$, which (between the said limits) becomes $\frac{2}{3} b\,t \sqrt{2g}\,(h^{\frac{3}{2}} - h'^{\frac{3}{2}})$: and if the orifice extended from the bottom to the top of the vessel, having then $x = h$, or $h' = o$, the expression would be $\frac{2}{3} bt \sqrt{2g}.h^{\frac{3}{2}}$. If a rectangular orifice of the same form and magnitude were situated at the bottom B, with its longer side ($= h$) horizontal, the breadth b being very small in this, and also in the preceding case, the quantity discharged in the same time t, the velocity of the effluent water being now equal in every part of the orifice, and being that which is due to the whole height h, would be expressed by $b\,t \sqrt{2g}\,h^{\frac{3}{2}}$. The discharge found above is manifestly equal to two-thirds of this quantity.

In the second book of the 'Principia,' Newton shows that all the particles of water issuing from an orifice in a vessel do not pass perpendicularly to the side or bottom in which it is formed, many of them converging towards the orifice in every direction; so that after passing it they form a stream of diminished breadth, which he called the *vena contracta*. The section of the *vena contracta* may be taken as equal to 5-8ths of the actual orifice, as has been shown by Mr. Rennie, in his 'Report to the British Association,' for 1834.

M. Savârt has demonstrated the existence of certain *eddies* formed at the orifice by the issuing jet, caused by some water above the orifice trying to get out and coming into contact with the resisting walls, and by some water below it being moved by the falling mass above it, thus producing a set of forces acting by couples. Hence the issuing water, although it always has its motion of *translation* perpendicular to the resisting surface, has, besides, a *rotatory* motion caused by these eddies. The irregularities of this rotatory motion then tend to cause a disintegration of each successive section; and hence, between the thicker or *normal* drops there come out smaller ones, thus forming an irregular stream of varying width. Savârt has shown that each drop is formed by an annular enlargement at the orifice, which is propagated along the jet and causes this disintegration by a succession of such pulsations. The number of these is probably *directly* as the velocity of the jet, and *inversely* as the size of the orifice. It is remarkable that these pulsations are continuous enough to cause a clear musical note; and if with any instrument we produce the same note near, the pulsations become very regular, but cause no change in the amount or velocity of emission. When the orifices are not circular, curious variations in the geometrical figures, representing the sections at different distances from the orifice, are produced.

When, again, a rising column of water impinges against a horizontal plate, we have a remarkable appearance,—namely, a sort of disc of water, of which the interior is a transparent sheet, and the outer rim is a streaked space, along which lines of fluid stretch out and fall back in a very fine spray. The pulsations here, also, are very regular, and produce a musical sound. The relative size of the striated part to the whole varies with the position of the intercepting solid. When a certain distance is reached this part vanishes, and we have a wholly transparent sheet. The forms also vary very beautifully, according as the plate is perpendicular or oblique to the issuing jet. M. Savârt has also given some curious results on the subject of the clashing together of two liquid veins, which we have not room here to describe, but which will be found in the 'Annales de Chimie et de Physique,' vol. liv.; and a brief summary in Pouillet's 'Traité de Physique.'

We have been recently enlightened as to the phenomena of issuing jets by the researches of MM. Savary and Magnus. Bidone asserted that the *spiral* form of the jet was illusory; but Savary, when accounting for the curious dilations which he calls *ventral segments*, showed that the efflux itself gives a vibratory motion to the liquid vein, thus causing the protuberances in question. Prof. Magnus, in the 'Phil. Mag.' for February and March, 1856, regards every jet as composed of an indefinite number of united jets. He then examines the effect produced by the collision of two equal jets, coming centrally in opposite directions. These, as we should suppose from Savârt's experiments, spread out at the confluence into a flat plate perpendicular to the axes of the jets. When they meet obliquely, but centrally, they form a flat plate, not circular, but oval. This also we should imagine *à priori*; for the force of each jet may be resolved into two others, one parallel to the plane bisecting the angle between the jets, and the other perpendicular to it. The latter causes the elongation of the plate in a plane perpendicular to the direction of the force, as in the former case. When the water thus spreads out laterally, its motion does not cease, but the plate, by its cohesion, contracts in width, and collects into two new jets converging to one another. These then throw out a new plate perpendicular to the first, and the same process is repeated, forming thus a succession of elliptic plates in perpendicular planes, like the links of a chain.

Again, if two jets meet obliquely, but not centrally, the liquid plate is still formed, but it is no longer flat, being twisted by its cohesion with the unimpaired parts of the jets.

From these two last cases especially, Prof. Magnus has shown the formation of a single jet from an orifice to be due to the clashing of several jets at the *vena contracta*, thus throwing out between them a plate of an elliptic form, and so on throughout the whole liquid vein. The *chain movement* of the jet thus produced is easily converted into a *spiral* one by any slight impediment at the orifice, or by currents, even very slight, in the cistern, since all motion whatever of water in a cistern *necessarily* resolves itself into *rotatory* motion; because all other motions are destroyed by the sides of the vessel. Besides this, even when there is *perfect* stillness in the water of the cistern, rotation will take place at an orifice, by reason of the motion of the earth. This is well illustrated by Foucault's pendulum experiment. [GYROSCOPE.] It is evident from this, that everything on the earth's surface has *two* motions *relatively to the earth*—namely: one round the earth's axis in 24 hours; and another round an axis in itself, and parallel to the former, in the same period. The *latter*, in the case of a vessel of water, is resolved into two, one parallel to the liquid surface, the other perpendicular to it; neither being visible, because the vessel and everything else have the same motion. The horizontal rotation, in the latitude of Great Britain, will be about ⅕° per minute, so that the liquid has the rotation about its *vertical* axis. This will be abundantly sufficient to show the cause of the *spiral* motion of the issuing jet.

Prof. Magnus, by introducing a *tranquilliser*,—that is, a fan consisting of four radiating plates,—in order to destroy the effect of this rotatory motion on the jet, succeeded in showing that, in this case, *no* ventral segments or any other irregularities were produced,—perhaps not even the *vena contracta;* but the issuing column was perfectly smooth and uniform. M. Plateau, however ('Phil. Mag.,' Oct., 1856), denies this statement, and shows, by reference to his celebrated method of destroying the action of gravity on fluid veins, that a liquid cylinder is in stable equilibrium when its length and diameter do not exceed the limit of 3 and 3·6, being in unstable equilibrium beyond this limit, so that it is ruptured spontaneously into a series of isolated spheres with alternating spherules. This effect of the formation of various-sized spheres is well shown in the fusion of a platinum wire by a strong electric current. The wire is first elongated, and then, by the rupture of equilibrium of the parts, resolves itself, just as a liquid jet, into spheroidal particles.

Lastly, with regard to the formation of the *vena contracta* in such cases, we shall see that it must be formed, if we consider the theorem of Torricelli, as correctly representing the approximate velocity of any affluent jet. By this theorem, as before shown, we have the velocity at the orifice given by the equation $v^2 = 2gs$, where s is the distance from the surface to the orifice. Now, g is about 32·2 feet for the latitude of London: hence $v^2 = 64{\cdot}4 \times s$

$$\therefore v = 8{\cdot}025 \times \sqrt{s}.$$

But it is shown by experiment, that this *theoretic* velocity (given by substituting any value for s proper for the vessel in question) is 1¼ times the *actual* velocity, or this latter is ⅘ of the former; so that we must reckon the actual *height* of the surface, not from the orifice, but from the *vena contracta* itself, in which case Torricelli's theorem is in accordance with experiment.

The distances, measured on a plane passing through the base of a vessel, to which fluids will be projected from orifices at different depths in its side, may be easily determined (the resistance of the air being neglected) by combining the action of gravity on the particles of fluid after they have left the orifice with the velocity communicated to them in consequence of the pressure arising from the depth of the orifice below the top of the column; and the path of the filament may be shown, as in the theory of gunnery, to be a parabolic curve.

The results of experiments tend to show that, when the height of a head of water in a vessel and the diameter of an orifice in its base or side are given, the discharge of water through an *ajutage*, or tube inserted in the orifice (its length not exceeding three or four times its diameter), is to that through the simple orifice, nearly in the ratio of 12 to 11; and it is observed that, with a given diameter at its farthest extremity, the tube which is formed to coincide as nearly as possible with the natural figure of the vena contracta affords the greatest discharge. When the tube is fixed vertically in the base of a vessel, the effect is increased in proportion nearly to the length of the tube; since the velocity at the lower extremity of the tube is that which is due not merely to the height of the fluid above the base of the vessel, but to the height above the extremity of the tube. Again, if a short tube be applied horizontally to an orifice in the side of a vessel, the part nearest to the vessel having the form of the vena contracta, and, from the narrow part of the tube, diverging conically to the opposite end, the discharge of water is found to be more abundant than from a tube whose form beyond the vena contracta is cylindrical. For when the water has filled the tube, the cylindrical stream through the contracted part communicates its motion laterally to the rest of the water, till it causes the whole to acquire the same velocity. The quantity discharged in this case, compared with that discharged from a cylindrical tube, is considered to be nearly in the ratio that the diameter of the conical tube at its extremity bears to that of the vena contracta. The following is the result of some experiments on this subject, showing the use of an ajutage:—

A vessel with a simple hole . . .	discharged	62	quarts in 100 sec.
A vessel with a pipe whose length = 2 diameters of the hole . . .	"	82	" "
A vessel with the same pipe inserted only half way in the hole . .	"	63	" "
When the bottom of the vessel = the parabolic curve described by the particles	"	92	" "
With a bell-mouth added to this . .	"	a maximum.	

It is customary to express the slope, or inclination, of a pipe or canal, when uniform, by the quotient arising from the division of the vertical height of one end above the other by the whole length. But, in the case of a reservoir, as A B, having a conduit-pipe D E; let A A′ be the surface of the water, and E, in the horizontal line F E, be the lower orifice of the pipe. Then, if A′G express the height due to the observed velocity at E, G F will be the height necessary to overcome the friction in the pipe, and $\frac{\mathrm{G\,F}}{\mathrm{D\,E}}$ is considered as the effective slope.

The passage of water through long pipes is greatly retarded by adhesion and friction in the interior, by the resistance experienced where bends take place, and by the disengagement of air, which remaining stationary in the pipes when the latter are laid along a level surface, or rising to the higher parts of any vertical bends, opposes an obstacle and sometimes entirely arrests the motion of the water. Experiments alone can, at present, afford information concerning the amount of the retardation in pipes of given lengths and diameters; and those which were conducted by the Abbé Bossut at Meziéres in 1779 are the most complete of any which have yet been made. The water was allowed to flow through pipes whose diameters were 1⅓ inch and 2 inches, and whose lengths varied from 30 to 180 feet. They were chiefly of tin, and were inserted in the side of a reservoir in which the water during any experiment was always kept at one height; which was either 1 foot or 2 feet above the axis of the pipe. The general rules deduced from the experiments are,—that the discharges in given times, with pipes of the same length and with the same head of water, are proportional to the squares of the diameters; and, when the diameters are equal, the discharges are inversely proportional to the square roots of the lengths of the pipes. In order to afford the means of obtaining by calculation the supply which may be expected from a pipe of given dimensions, it may be assumed that when a pipe is 30 feet long and 1⅓ inch in diameter, the discharge at its extremity is about one-half of that which would be obtained from a simple orifice, or short tube, of the same diameter. The experiments made by M. Couplet at Versailles, in 1730, were with pipes whose lengths varied from 280 to 2340 fathoms, and the diameters from 4 to 12 inches. The pipes were of iron or stone, or of both combined, and they were bent in various directions both horizontally and vertically. A pipe whose length was 600 fathoms, and which was 12 inches in diameter, when the head of water was 12 feet, afforded a discharge amounting to about ⅒th; and a pipe of equal diameter, whose length was 2340 fathoms, when the head of water was 20 feet, discharged only ⅒th, of that which would have been obtained from a simple orifice. Bossut found that, in order to produce a continued discharge in a pipe, the head of water should be about 1⅓ inches in 180 feet.

The motion of water in the bed of a river depends on the action of gravity, by which the particles endeavour constantly to descend, and on the mobility of the particles, by which they are enabled to assume a level surface when at rest. The descent by gravity takes place in consequence of the difference, in a longitudinal section of the river, between the levels of any two points on its surface, whatever be the form of its bed; since the molecules of water, which are in every part of a transverse section, have equal facilities of moving in the direction in which, from the general slope, the motion can take place. And, by the nature of an inclined plane, the accelerative force by which a particle is moved is to that of gravity as the difference of level between any two points at the surface in a longitudinal section is to the distance between those points *on* the surface. That the motive force of the molecules composing a river depends on the upper surface only may be easily admitted, when it is considered that the bed may have any inclination and any degree of irregularity, yet if the upper surface be horizontal the water will be at rest.

If the water of a river experienced no resistance from the sides and bed, its motion would go on continually accelerating from its source to its mouth, like a solid body falling by the action of gravity; and the consequence would be, that besides the destruction ensuing from the violence of the torrents in the lower lands, the moisture would be drawn from the soils in the upper regions, which would thus become incapable of supporting vegetable and animal life. The adherence of the particles of water to each other, and the friction against the beds, produce together a resistance which increases with the velocity of the current, and becomes at length equal to the accelerative force of the descent; and then a uniform motion is established.

But when a current is in a state of equilibrium, the velocities in different transverse sections of the river may be very unequal, on account of the variations in the areas of those sections, through all of which the same quantity must flow in the same time; since otherwise the equilibrium of the river would not be permanent. It follows that the products of the areas of the sections multiplied by the velocities in each must be equal to each other, and that the velocities in different sections must be inversely proportional to the areas of those sections.

If the difference of level between any two points on the surface of a river or canal, in a longitudinal section, be equal to one inch, and if l, in inches, be the distance of those points on the surface, the slope of the river may be represented by $\frac{1}{l}$. Then, since the accelerative power of gravity vertically, is to the accelerative power on any plane, as the length of the plane is to its vertical height; we shall have $\frac{g}{l}$ for the accelerative power in a river whose slope is $\frac{1}{l}$. Again, if the resistances to the motion of the fluid were, as is sometimes the case, nearly proportional to the squares of the velocities, so that the resistance might be represented by $\frac{v^2}{m}$ (m being constant, and v representing the mean velocity); then (because when water in a river moves uniformly, the resistance is, as in all like cases, equal to the accelerative force) we should have $\frac{v^2}{m} = \frac{g}{l}$; whence $v = \sqrt{\frac{mg}{l}}$. But the resistances in canals and rivers are not strictly proportional to the squares of the velocities; and it is found by experiment that, in one and the same bed, $v \left\{ \sqrt{l} - \text{hyp. log.}\ \sqrt{l + 1{\cdot}6} \right\}$ may be considered as constant, and may be represented by $\sqrt{mg}$. Also, in beds whose transverse sections differ both in area and figure, when the mean radius is represented by r (where

$$r = \frac{\text{area ACB of the section}}{\text{arc ACB}} \Big) \textit{fig. } 2.$$

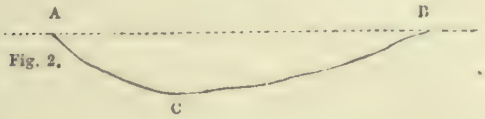


Fig. 2.

it is found by experiment that $\frac{\sqrt{mg}}{\sqrt{r} - 0{\cdot}1}$ is constant and equal to 307 inches; hence $\sqrt{mg} = 307\ (\sqrt{r} - 0{\cdot}1)$ and $m = 244\ (\sqrt{r} - 0{\cdot}1)^2$. Consequently we obtain

$$v \left\{ \sqrt{l} - \text{hyp. log.}\ \sqrt{l + 1{\cdot}6} \right\} = 307\ (\sqrt{r} - 0{\cdot}1),$$

or $v = \frac{307\ (\sqrt{r} - 0{\cdot}1)}{\sqrt{l} - \text{hyp. log.}\ \sqrt{l + 1{\cdot}6}}$. But further investigation leads to the conclusion that this expression for v must be diminished by $0{\cdot}3\ (\sqrt{r} - 0{\cdot}1)$ on account of the resistance by which the particles of water oppose a separation from each other. (Du Buat, 'Traité d'Hydrodynamique.')

As an approximation we may make $\sqrt{mg} = 307\ \sqrt{r}$, and $v = 307 \sqrt{\frac{r}{l}}$. And by experiment it has been found that if v' = the velocity at the surface of a river, v'' the velocity at the bottom, and v the mean velocity (all being expressed in inches per second), we shall have

$$v'' = (\sqrt{v'} - 1)^2 \text{ and } v = \tfrac{1}{2}\,(v' + v'').$$

The mean velocity in any one section may be practically found, tolerably near the truth, by placing in it a rod of wood loaded at one end with a weight sufficient to allow it to float upright in still water. The greater velocity at the upper surface will make the rod incline towards the direction of the stream; and, consequently, when it has acquired a state of equilibrium, it will float in an oblique position: the top of the rod will move slower than the water at the upper surface of the river, and the bottom will move faster than that in the lower part. Hence the mean velocity of the water in that part of the breadth of the river may be considered as equal to ·8 of the observed velocity of the rod. Often a Woltmann's drum is used, in which is a turning shaft, communicating by a screw-channel with a meter, and carrying four wings like a windmill. The experiment must be tried in different parts of the breadth of the river; and, in order to find the quantity of water which flows through the section in a given time, the area of the section must be obtained by measuring the breadth and sounding the depths at intervals across the river.

A knowledge of the velocity at the bottom of a river is of considerable use in enabling the hydraulic engineer to judge of the action of the stream on its bed; and it is evident that, to ensure permanency, the accelerative force of the water should be in equilibrio with the tenacity of the channel. The following table shows the superior limits

of the velocity which the water should have at the bottom of canals, according to their nature, without wearing them away:—

Weakened earth	2·5	inches per second.
Light soft clays	4·9	"
Sand	9·8	"
Gravel	19·7	"
Pebbles	19·9	"
Broken stones, flints	39·4	"
Agglomerated pebbles and schist	49	"
Rocks in layers	59·1	"
Hard rocks	98	"

Irregularities in the sides and beds of rivers, whether arising from natural causes, or produced by artificial obstructions, are the causes of currents setting obliquely across and of eddies being formed. These not only diminish the velocity of the water by creating impediments to its motion, but are sometimes seriously detrimental to the navigation, and to the stability of the structures which are founded in the bed of the river. When walls are made to project into the stream, the water striking them is forced to rise above its general level, on account of the obstruction; and is afterwards reflected towards the middle of the channel, with a velocity due to the rise thus produced. This current carries with it, by a lateral communication of motion, some of the water from the parts beyond the obstruction; the surface of the river being here, consequently, depressed, a portion of the water from the oblique current falls by gravity into the lower part, and thus a sort of whirlpool is formed at the place where the obstruction terminates. This process goes on continually; and the pressure upon the bed of the river under the whirlpool being diminished in consequence of the centrifugal force arising from the spiral motion, the water under the bed forces its way upwards, removing the gravel and sand, and frequently displacing the materials which form the foundation of the work there constructed.

When a body moves in a fluid at rest, its anterior surface being perpendicular to the direction of the motion; if an indefinitely thin lamina of fluid be supposed at every successive instant of time to be displaced, the resistance experienced by the moving surface may be considered equal to the weight of a column of the fluid whose base is the surface pressed, and whose height is that which is due to the velocity: that is to say, the resistance may be supposed to be equal to the pressure which would produce the same velocity at an orifice in the base or side of a vessel. A difference of opinion has however existed respecting the amount of the pressure sustained by the moving surface. For a vein of water issuing from a vessel and striking a plane surface at rest is shown by Newton ('Principia,' lib. ii., prop. 36), (and the fact seems to be confirmed by the experiments of Krafft and Bossut), to exert a pressure upon that surface equal to the weight of a column of water whose height is twice that which is due to the velocity. Du Buat, however, has proved that, even if such should be the case with respect to the central part of the impinging column of fluid, the mean pressure is less, on account of the lateral deviations of the exterior filaments, and the amount first stated above is that which is generally assumed.

If the velocity be represented by v, the height due to that velocity is equal to $\frac{v^2}{2g}$; then a representing the area of the moving surface, and D the specific gravity of the fluid, we shall have $\frac{a v^2}{2g}$ D for the pressure against, or the resistance experienced by that surface in moving through the fluid.

But when the anterior surface of the moving body is oblique to the direction of the motion, the resistance above found must be diminished on account of the inclination. Thus, let I be that inclination; the number of parallel filaments which act against a plane perpendicularly is, to the number which can act upon it in an oblique position, as radius (=1) is to sin. I. And by mechanics, the intensity of any force acting obliquely on any plane is a decomposed part of the whole force, and is to the latter in the ratio of sin.^{2} I to rad.^{2} (=1). Therefore the effective pressure against an oblique plane varies, as sin.^{2} I; consequently when the moving plane is oblique to the direction of its motion, the resistance which it experiences is to be expressed by $\frac{a v^2}{2g}$ D sin.^{2} I.

If a cylindrical body, terminated in front by an equilateral cone, move through a fluid in the direction of its axis; it can easily be shown that the resistance experienced is one-fourth, and if the body be terminated in front by a hemisphere, the resistance is one-half of that which would be experienced by the same cylinder if it were terminated in front by a plane perpendicular to its axis.

When a prismatical body is placed in a stream of water the effort necessary to keep it immovable in the fluid is equal to the difference between the pressures in front and behind. The pressure in front is equal to the sum of the pressure produced by the moving water and of the dead pressure, as it is called, which takes place when the body is at rest in still water; and the pressure on the rear face is merely equal to this last. When a body of that kind is made to move in a fluid at rest, its progress is retarded by the same difference of the pressures before and behind, and by the friction of the water against the sides. Additional causes of retardation are the heaping up of the water in front when the velocity is considerable, and a diminution of the pressure on the hinder face on account of the surface of the water there being depressed below the general level; a circumstance arising from the lateral communication of motion in fluids, by which the water, driven off from the front, and proceeding in a diverging direction on each side towards the rear, carries away with it from thence some of the water which should counteract in part the pressure on the front.

Mr. Scott Russell in the 'Report of the British Association,' for 1835, and Mr. Macneill in the 'Transactions of the Institution of Civil Engineers,' have given the following laws for the *resistance* to boats moving on canals; but for the practical reading of these laws we must refer to STEAM-BOAT.

1. The rise or emergence depends on the velocity of the vessel.
2. The resistance depends on the velocity or magnitude of the wave which is generated.
3. The resistance increases rapidly as the velocity of the body approaches the velocity of the wave, and is a *maximum* when they are equal.
4. If the velocity of the body be greater than the velocity of the wave, the resistance diminishes; for the body is poised on the summit of the wave in stable equilibrium.
5. The velocity of the wave is independent of the breadth of the fluid, but varies as the square-root of the depth.
6. In every navigable river there is a velocity with which it is easier to ascend against the current, than to descend with it.
7. Vessels on the summit of the wave *may* move about 20 or 30 miles per hour.

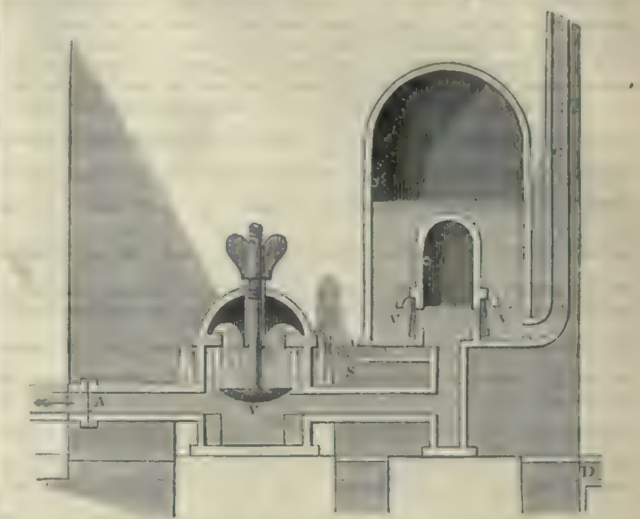
With regard to the form of vessel best adapted to diminish this resistance, they add:—

1. A cylinder will meet with *less* resistance in a fluid than a plate of the same dimensions as the end of the cylinder; and a cone with its *butt-end* foremost is better than either.
2. There is no fixed ratio of breadth to length which is best. The longer the better, but the breadth varies with the burden.
3. The section of greatest breadth should be always *abaft* the middle, about 3-5th of the length from the bow.
4. Lastly, the water-lines should be hollow, of the form called the "*wave-form*," first concave, then convex.

We may conclude this article with a notice of one of the many hydrodynamic engines, referring to separate heads, as indicated under HYDRAULICS, for other contrivances, in which the water is to be raised, or the force of water to be employed.

The HYDRAULIC RAM, which was invented by Montgolfier at the close of the last century, and improved by his son, consists, independently of the feeding cistern, of a pipe which carries the water to the head of operations. This part consists of a short tube, at the upper part of which, as well as at the end, are two valves, the *stop-valve*, and the *ascension-valve*; the extremity is in a bell filled in its upper part with air, and its lower with water. The ascension-valve being closed, the water will come from the reservoir with increasing velocity; and leaving it by the stop-valve, will shut it: then, by the *vis viva* which it has acquired, it will strike the ascension valve, and open it, and so penetrating into the reservoir of air, will compress it, and make the water in the ascension-tube rise; then the elasticity of the air, and the weight of water in the ascension-pipe will, of course, absorb partly the *vis viva* acquired with the water and will give it a powerful motion; hence, by reason of the retrograde motion of the water, the ascension-valve will shut, and there will be formed a partial vacuum under the stop-valve, which will open, and so on continually. Hence this machine, when once set in motion with a continual supply of water, will work by the momentum generated and destroyed for any length of time, if kept in repair.

The accompanying figure represents a vertical section of the improved construction. The water arrives from a cistern at a higher level, by the horizontal pipe A, over which is a circular opening containing a valve V, which acts as a *stoppage valve*, and is suspended by a stem. Further on the pipe ascends into a small reservoir C, called the *air matrass*; the air contained in it is compressed by the ascending water, while the lateral pressure of the water opens the valves V V′, and enters the larger reservoir F, which it partly fills, and compresses the air confined in the other part of it. The reaction of this air on the surface of the water causes the water to ascend the force-pipe G. When the stoppage valve is down, as in the figure, the water overflows the opening above it, and passes into a waste reservoir, thereby producing a rapid increase in the velocity of the current in A, which, acting on the under surface of the valve, forces it up, and closes the opening by which the water escapes. This momentary confinement of the water causes it to force its way into the cylinder C, where it compresses the air and produces a reaction, which opens the valves V V′, and a portion of the water enters the vessel F, and further compresses the air there. These resistances retard the current A, and relieve the stoppage valve from the impulse which raised it, so that that valve again falls, and the valves V V′ are closed. The water again escapes from the opening over the stoppage valve as shown in the figure, the current in A is again accelerated; the stoppage valve is once more closed, and the same series of effects is repeated. In this way by a series of pulsations water is continually elevated in the pipe G. As air is gradually absorbed by water, the compressed air of the vessels C and F is liable to be carried away by the water up the force-pipe G, the effect of which would be to subject the machine to shocks which would destroy the uniformity of its action and injure its working parts. To prevent this, an air-valve is provided at S, which, opening inwards, admits air during the intervals when the stoppage valve is closed. The air in rushing through the valve S makes the sound like the sniffling of a person's nose, and is hence called a snifting valve. It may consist of a tube of capillary bore, and be left entirely open.



HYDRO-ELECTRIC MACHINE. [ELECTRICAL MACHINE.]

HYDROFERRIDCYANIC ACID. [FERRIDCYANIC ACID.]

HYDROFERROCYANIC ACID. [FERROCYANIC ACID.]

HYDROFLUOBORIC ACID. [FLUORINE.]

HYDROFLUORIC ACID. [FLUORINE.]

HYDROFLUOSILICIC ACID. [FLUORINE.]

HYDROGEN (H), an elementary body, which, as it is known only in the aëriform state, is usually termed hydrogen *gas*. From the earliest dawn of chemical science, elastic fluids have been known which had the property of burning on the approach of flame, and were confounded under the general name of *inflammable air*. As it was afterwards found that there was a difference in their densities, they were distinguished as *light* and *heavy* inflammable air; it is the former of these which is now called hydrogen. Hydrogen gas was first minutely examined, and the mode of preparing it in various ways stated, by Mr. Cavendish. [CAVENDISH, HENRY, in NAT. HIST. DIV.]

In nature, hydrogen is found in the free or uncombined state, as a constituent of volcanic gases. In comparatively small quantity it occurs associated with phosphorus, sulphur, carbon, and nitrogen, forming gaseous compounds; it is a constituent of nearly all the proximate principles contained in animals and vegetables; but united with oxygen, it constitutes $\frac{1}{9}$th of the total weight of that familiar compound—water.

Hydrogen is always prepared from water. If the gas is required absolutely pure, the water is decomposed by a current of electricity, the hydrogen being collected from the negative pole of the decomposing cell, and, if necessary, dried by being passed through a tube filled with pieces of chloride of calcium. Another process, valuable because instructive, consists in passing a fragment of potassium or sodium up into a small quantity of water in a test tube, the remaining portion of which is filled with mercury, and inverted over the mercury trough; the sodium rapidly attacks the water, combining with its oxygen to form oxide of sodium (soda), and displacing its hydrogen, which latter element, being gaseous, expels the greater part or all of the mercury from the tube. The following is the simple change that takes place:—

$$\underbrace{\mathrm{Na}}_{\text{Sodium.}} + \underbrace{\mathrm{HO}}_{\text{Water.}} = \underbrace{\mathrm{NaO}}_{\text{Soda.}} + \underbrace{\mathrm{H}}_{\text{Hydrogen.}}$$

For ordinary purposes, hydrogen is prepared by acting upon granulated zinc with diluted sulphuric acid. The zinc, covered with water, is placed in a bottle or other convenient vessel to which a cork can be fitted, and strong sulphuric acid is then poured in by means of a funnel, to which is attached a tube passing through the cork to the bottom of the bottle. The gas is rapidly disengaged, and passing through an exit-tube in the cork may be conveyed by flexible tubing into a gasholder, &c. [GASES, COLLECTION OF.] In this process, sulphate of zinc is formed, which remains in the generating vessel dissolved in the excess of water used.

$$\mathrm{Zn} + \mathrm{HO, SO_3} = \mathrm{ZnO, SO_3} + \mathrm{H}.$$

If it be required to produce hydrogen cheaply, though in a very impure state, it may be readily done by passing steam over iron borings heated to redness in a piece of iron gas-pipe. Under these circumstances the iron is converted into an oxide (Fe_3O_4), and the hydrogen set at liberty.

Hydrogen is an element. No amount of pressure causes it to abandon its gaseous condition. When pure, it is colourless, tasteless, transparent, and inodorous. It is the lightest body in nature, being sixteen times lighter than oxygen, and fourteen and a half times lighter than atmospheric air; its specific gravity is, therefore, 0·0692, air being taken as unity. One hundred cubic inches of it weigh only 2·14 grains.

This gas extinguishes flame; but when it meets with a supporter of combustion, as oxygen, it burns readily, with a continuous but feeble flame, generating much heat. When mixed with half its volume of oxygen, and the mixture is ignited by a taper, or by throwing into it a small quantity of platinum black, immediate and loud explosion ensues, attended with the formation of water by the combination of the gases; hence the name *hydrogen*, or the *water-producer*, from *ὕδωρ*, "water," and *γεννάω*, "I generate." It is irrespirable for any length of time, but when inspired for a short period it renders the voice remarkably but not permanently shrill; it does not appear to be poisonous, for when mixed with a due proportion of oxygen it may be respired without inconvenience; when it proves fatal, it seems to do so by the mere exclusion of oxygen.

It is very sparingly soluble in water, 100 cubic inches taking up only about one inch and a half of the gas; nor is there any other liquid which is capable of dissolving it in notable quantity. Hydrogen, neither in the gaseous state nor in solution, possesses either acid or alkaline properties. In its combinations it is powerfully electro-positive, and chemically plays more the part of a metal than of a metalloid.

In its separate state, hydrogen has not been applied to any very useful purpose; but on account of its extreme lightness it has been used to fill air-balloons; at present, however, coal-gas is substituted for aëronautic purposes, by reason of the facility with which it is obtained. This, however, from its greater density, requires much larger balloons than hydrogen gas.

When mixed with oxygen gas, and the mixture gradually burned in a small jet issuing from such a blowpipe as is described under Drummond Light, a temperature is produced sufficiently intense to melt platinum; and even if burned in the air, the oxygen of which serves as a supporter of combustion, a considerable degree of heat is generated.

When a very small jet of hydrogen gas is burned, the flickering nature of the flame causes musical sounds when a tube of glass or metal, or even of paper, is held over it. Such an arrangement is known as the hydrogen harmonicon, but any combustible gas will produce a similar effect.

The equivalent of hydrogen is 1, and its combining volume 2. Its combinations with other elements or radicals are called *hydrides* or *hydrurets*.

Hydrogen combines with oxygen in three different proportions, forming,—

1. Protoxide.	HO	water.
2. Binoxide	HO_2	oxygenated water.
3. Teroxide	HO_3	ozone.

1. *Protoxide of Hydrogen*, or *Water* (HO) will be treated of in a special article. [Water.]

2. *Binoxide of Hydrogen* (HO_2). To prepare this compound, twelve parts of binoxide of barium, obtained by passing oxygen gas over baryta heated to low redness, are dissolved in two hundred parts of water containing as much hydrochloric acid as will saturate about fifteen parts of baryta. Solution having been effected by gentle stirring, the whole of the baryta is then precipitated by a slight excess of sulphuric acid, added drop by drop. Another twelve parts of binoxide of barium are now added, and the precipitation of the baryta effected as before. This process is continued until about one hundred parts of binoxide of barium are consumed, care being taken to keep the mixture well cooled, and to filter it after every other addition of the binoxide. A tolerably strong solution of binoxide of hydrogen is thus obtained, containing, however, much hydrochloric acid. The latter is removed by the addition of sulphate of silver, and the sulphuric acid thus introduced got rid of by carbonate of baryta. Finally, the solution is placed in vacuo over sulphuric acid for a few days, when the water evaporates and leaves the binoxide of hydrogen. The latter body also volatilises in vacuo, but far less quickly than water.

Binoxide of hydrogen thus prepared must be kept in long glass tubes, closed with stoppers, and surrounded with ice. Notwithstanding these precautions, however, it slowly decomposes into water and free oxygen gas. It is a colourless, transparent liquid, of sp. gr. 1·452. It is unaltered by a temperature 54 degrees below the freezing point of water. It has a harsh, bitter taste, bleaches litmus paper without reddening it, and when placed on the hand whitens the cuticle and produces violent itching. Heat rapidly decomposes it. Contact with most metallic oxides not only causes violent separation of oxygen, but at the same time the oxides themselves are reduced to the metallic state. Binoxide of hydrogen appears to combine with some of the hydrated acids, as it is far less decomposable in their presence than when alone.

Oxygenated water is a term that has been applied to binoxide of hydrogen, but is now usually restricted to the solution formed by saturating water with oxygen gas.

3. *Teroxide of Hydrogen* (HO_3). The gases that are evolved when water is decomposed by a current of electricity are well known to possess a peculiar odour. The body that communicates this property has for some years been called *ozone* (from ὄζω, "I smell"); but it is only recently that M. Baumert has proved it to be the teroxide of hydrogen. The presence of hydrogen in this remarkable compound M. Baumert demonstrated by passing the gases (oxygen and ozone) evolved from the positive pole of a water-decomposing apparatus through a long drying tube containing pumice-stone moistened with sulphuric acid, and then through a tube the inner surface of which was coated with anhydrous phosphoric acid, and one portion of which was gently heated; water was thus produced, and made evident by the solution of the film of phosphoric acid on that part of the tube through which the gas was making its exit, while the film on the opposite part was quite unaltered.

Teroxide of hydrogen decomposes iodide of potassium, the excess of oxygen it contains—over and above that necessary to form water with its hydrogen—liberating its equivalent of iodine from the iodide of potassium, just as chlorine or bromine does. Taking advantage of this fact, M. Baumert ascertained the composition of ozone, prepared as above, by passing the gas for several hours through a weighed bulb apparatus containing iodide of potassium solution, with an arrangement for preventing loss of water by evaporation. The increase in weight after that time gave the quantity of ozone that had passed into the apparatus; an estimation of the iodate of potash formed, showed how much oxygen, exclusive of the elements of water, was contained in that weight of ozone, while the difference between the weight of the oxygen and the total increase in weight of the apparatus, gave the weight of water that had been formed from the decomposition of the ozone. The mean of three such experiments proved that the ozone in question was teroxide of hydrogen, thus:—

	By calculation.	By experiment.
H . . .	4	4·1
3O . . .	96	95·9
HO_3	100	100·0

Other Compounds of Hydrogen.—With sulphur, selenium, iodine, bromine, chlorine, fluorine, and tellurium, hydrogen forms combinations called *hydracids*. With nitrogen, it forms the powerful salifiable base ammonia; and with phosphorus, arsenic, antimony, and potassium, it forms the several hydrides. A description of each of these compounds will be found under the name of the element with which the hydrogen is united.

HYDROKINONE. [Kinonic Group.]

HYDROLEIC ACID. [Oleic Acid.]

HYDROMARGARIC ACID. [Margaric Acid.]

HYDROMARGARITIC ACID. [Margaric Acid.]

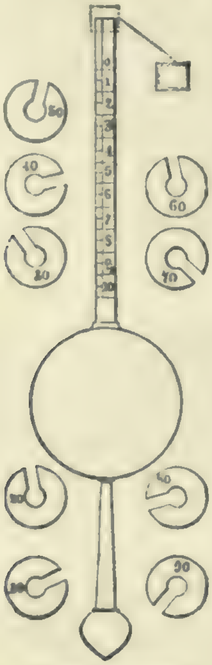
HYDROMELLON. [Mellon.]

HYDROMELLONIC ACID. [Mellonic Acid.]

HYDRO'METER (ὕδωρ, water, and μέτρον, a measure) is an instrument for determining the relative densities or specific gravities of fluids. The principle of the hydrometer is this: It is known that when a body is immersed in a fluid, it loses as much of its weight as is equal to the weight of that portion of the fluid which it displaces. [Hydrostatics.] Thus, if a body suspended from the extremity of one arm of a balance be counterpoised by weights applied to the other arm, and while thus suspended it be immersed in a vessel of water, it will be found that one arm of the balance will preponderate, and that, in order to restore the equilibrium, as much weight must be applied to that arm from which the body is suspended as is equal to the weight of the water displaced. Hence, if the same body be immersed successively in two different fluids, the portions of weight which it will thereby lose will be directly proportional to the specific gravities of those fluids; because the diminution of weight is always equal to the weight of the fluid displaced,—that is, to the magnitude of the body multiplied into the specific gravity of the fluid. The above supposes the body to be specifically heavier than the fluid. If it be lighter, it will float upon the surface, so that its tendency to descend, or its weight, will then be entirely counteracted by the fluid; from which it appears that, when a body floats upon the surface of a fluid, the weight of the portion of fluid displaced is equal to the entire weight of the body. Now, since the weight of the fluid displaced by a floating body is constant (being always equal to the weight of the body), whatever may be the density of that fluid, it is obvious that if we can determine how much of the body is immersed, we may immediately deduce the specific gravity of the fluid; because, when the weight is constant, the specific gravity varies inversely as the bulk.

Upon this principle is constructed the instrument known by the name of *Sykes's hydrometer*, which is that employed in the collection of the spirit revenue of Great Britain. It consists of a thin brass stem about six inches in length, passing through and soldered to a hollow ball of the same material, and about one inch and a half in diameter.

To the inferior extremity of the stem, from which the hollow ball is about one inch distant, a permanent pear-shaped weight is attached; so that when the instrument is placed on a fluid, the other extremity may float perpendicularly to the surface. There are also ten weights of different magnitudes, nine of which are circular, and applicable by means of a slit to the lower branch of the stem. These are marked 10, 20, 30, 40, 50, 60, 70, 80, and 90 respectively, and by their successive application the instrument may be sunk so as to obtain the complete range of specific gravity, from that of pure alcohol to that of distilled water. The other weight is of the form of a parallelopiped, and may be fixed when necessary to the upper branch of the stem. The upper branch of the stem is divided into ten equal parts or degrees, each of which is subdivided into two parts. The whole is adjusted at the temperature of 60° Fahr., and tables are computed whereby the necessary corrections may be determined for all variations above or below that point. In order to determine the strength of spirit by means of the hydrometer, a portion is placed in a tall glass cylinder, and the temperature observed. One or more of the circular weights is then attached to the lower stem of the instrument, so that the lower extremity of the scale may sink beneath the surface of the fluid, and when the whole has become stationary the number upon the scale in contact with the surface of the fluid is observed. This number added to the number marked upon the circular weight employed will give a third number, adjacent to which, in the tables above mentioned, and under the head of the proper temperature, will be found the per centage of strength required.



Sykes's Hydrometer.

The most convenient method of obtaining the specific gravities of fluids is by means of what chemists call a *specific gravity bottle*, or *a thousand grain bottle*. This is a bottle of a globular form, with a ground-glass stopper, so adjusted as to contain exactly 1000 grains of distilled water, at the temperature of 60° Fahr., and accompanied by a weight, which is an exact counterpoise for the bottle when thus filled. In order to determine the specific gravity of a fluid by this means, it is simply necessary to fill the bottle with that fluid at the temperature of 60°, and place it in one of the scale-pans of a delicate balance, the counterpoise being placed in the other scale-pan; then the number of grains which it will be found necessary to add to one of the scale-pans, in order to produce equilibrium, will be the difference between the specific gravity of the fluid and that of water taken at 1000. For example, the bottle filled with the sulphuric acid of commerce will require about 845 grains to be added to the counterpoise to produce equilibrium, whence we say that the specific gravity of such a sample of sulphuric acid is 1·845. Whereas if the bottle were filled with spirit of wine, we should have to add weights to the scale-pan containing the bottle, and in the case of what is called *proof spirit*, 80 grains would have to be so added, in which case the specific gravity would be 0·920. [Alcoholometry; Specific Gravity.]

Various forms of hydrometer have been contrived under different names, one or two of which we may mention, such as the *Aræometer* (from *ἀραιός*, "light" or "thin," and *μέτρον*, "a measure"). This is employed for the purpose of ascertaining the specific gravities of fluids, generally such as are less dense than water, but it may be used to determine those of any fluids, and also of solid bodies. Its best form is probably that which was devised by Nicholson. The instrument which bears the name of that experimenter consists of a hollow cylinder, or sphere, of copper, from each extremity of which proceeds a stem; that which, when the instrument is in a vertical position, is uppermost, is a wire of hardened steel about 1-40th of an inch in diameter, carrying at its top a small cup, in which weights may be placed: to the lower stem, which is short, is attached a stirrup carrying a cup in which may be placed a solid body whose specific gravity it may be required to determine. The instrument is so adjusted, that if a weight equal to 1000 grains be placed in the upper vessel, the whole will sink in distilled water at the temperature of 60° Fahr., till a mark made on the stem is on a level with the fluid surface. When the specific gravity of a fluid, whether lighter or heavier than water, is to be determined, the instrument is plunged into the fluid, and weights are placed in the upper vessel till the mark on the stem is at the surface; then, if w in grains be the weight of the instrument when unloaded, and w' the weight placed in the vessel as just said: also if s be the specific gravity of distilled water, and s' that of the fluid in which the instrument is placed, we have, by hydrostatics,

$$w + 1000 : w + w' :: s : s';$$

whence s' may be found.

To obtain the specific gravity of a solid which does not imbibe water: after placing the instrument in distilled water, let the body be laid in the upper vessel, and weights, in grains, added till the mark on the stem is at the level of the surface; these weights being subtracted from 1000 grains, leave the weight of the body in air; then placing the body in the lower vessel, let other weights be added in the upper one till the mark on the stem is again at the surface of the water; these additional weights will express the loss which the body sustains by being immersed in water. Consequently if w'' be the weight of the body in air, w''' the loss just mentioned, s the specific gravity of the water, and s'' that of the body, we have by hydrostatics,

$$w''' : w'' :: s : s'';$$

whence s'' may be found.

If the substance whose specific gravity is required be, like wood, capable of imbibing water during the experiment, it should be left in the lower vessel, while under water, till the instrument is stationary, when the additional weights in the upper vessel will express the weight of the displaced water, together with that which is imbibed; then, having dried the surface, let the substance be placed in the upper vessel and weighed in air as at first: the difference between this weight and that which was found before the substance was put in the water, is the weight of the water imbibed; and this must of course be subtracted from the observed weight of the substance in water, previously to substituting the values of the terms in the last proportion.

For fluids of greater specific gravity than water, such as the concentrated acids, an instrument of the like kind which was invented by Guyton de Morveau, and is designated "gravimeter," may be used. (Gregory's 'Mechanics,' vol. ii.) Instruments of this kind, however, are seldom resorted to, the best plan being to make use of the hydrostatic balance, as will be more particularly described under Specific Gravity.

HYDRONITROFERROCYANIC ACID. [Cyanogen.]

HYDRONITROPRUSSIC ACID. [Cyanogen.]

HYDROPERSULPHOCYANIC ACID. [Cyanogen.]

HYDROPHO'BIA (from ὕδωρ, water, and φόβος, fear) is the disease occasioned by inoculation with the saliva of a rabid animal, and is so called from the violent and suffocating spasms of the throat which occur when the patient attempts to drink, or when, in the latter stages, the mere idea of drinking arises in his mind. The disease is never produced in man by any other cause than the saliva of a rabid animal: those cases which have been said to arise spontaneously have not presented all the true characters of the affection, and have in general been only severe cases of hysterical or other convulsions, in many of which the imagination and the fear of real hydrophobia had much influence. Whether it is ever spontaneously generated in animals is less certain, because its origin in them is less easily traceable; but the fact that it is possible to ward off the disease from packs of dogs, in which every fresh comer is submitted to a kind of quarantine, and the many instances now known of isolated situations in which, although dogs are very numerous, no case of hydrophobia has occurred for many years, tend to prove that in the dog also it arises only in consequence of the bite of some other rabid animal. It is probable that all animals are subject to hydrophobia, for all that we have an opportunity of observing, that is, all our domestic species, are; but it has not appeared that any, except the wolf, fox, cat, and dog, are capable of communicating it to each other, or to other species. There is no evidence whatever to prove that the disease can be communicated from one human being to another; men affected by it are not disposed to bite, and it is doubtful whether, if they did bite, the saliva would have any effect, for the experiments made with it upon animals are as yet contradictory and inconclusive.

The disease may be communicated to man either by the saliva being carried into a wound made by the tooth of a rabid animal, or by its being placed on the surface of a previous wound, as where dogs have licked the hand or face of a person on which there was any raw surface. However, it is only a small portion of the bites which a mad animal gives that convey the disease; if, for example, he bites through the clothes, there is a great probability that all the saliva will be wiped off from his teeth as they pass; and hence wounds of the hands and face are generally the most dangerous. It is probable, too, that the saliva differs in the degree of its virulence in different animals; the bite of the mad wolf seems generally more fatal than that of the dog. In a case known to John Hunter, twenty-one persons were bitten by the same dog, and only one had hydrophobia; in another, a wolf bit seventeen persons at Brive, and of these ten died by hydrophobia; in a third, fifteen persons were bitten by a dog, in ten of whom the wound was on the flesh, and three died. In none of these cases had any preventive measures been used; and from the evidence collected from various sources, Dr. Hamilton ('Remarks on Hydrophobia,' vol. i.) thought that whether preventive means were employed or not, only one person in twenty-five of those bitten by mad dogs would have hydrophobia. It appears that animals are more subject to the disease than man; for in a case where a dog bit four persons and twelve dogs, all the dogs died, but not one of the men. These results, although they should not prevent the surgeon from employing those measures which prevent the disease, fully explain how empirical remedies have obtained so much credit, the immunity from the disease being attributed to their influence, when it would have been as complete if they had never been used.

The period after the inoculation at which the symptoms of hydrophobia may exhibit themselves varies greatly. In the ten persons already mentioned who were bitten by the wolf, one was affected on the sixteenth and another on the sixty-eighth day after their wounds were received; in the five bitten by the same dog, the deaths occurred between the thirtieth and sixty-third days. In general the disease appears between the thirtieth and fortieth days from the injury; but cases are known where it has been delayed as long as eighteen months, and Dr. Bardsley believes that a person who has been bitten and used no preventive measures cannot be considered as perfectly safe till at least two years have elapsed. Cases are indeed recorded in which there was no evidence of injury for ten and twelve years before the disease manifested itself, but at present neither the number nor the accuracy of such histories is sufficient to allow any safe conclusion to be drawn from them.

The bite of a rabid animal generally heals up like that of a healthy one; there is nothing whatever which would indicate danger from it, and the patient is attacked when he has forgotten that he was ever bitten. In some cases, however, before hydrophobic symptoms appear, the scar of the wound becomes painful, red, and swollen, and pain is felt shooting from it along the course of the nerves of the part, as if it were going to ulcerate. The first decided indication of the disease is that the patient has headache and general uneasiness; he loses his appetite, and when he is about to drink he suddenly feels an aversion to any liquid, and is choked by any attempt to swallow it. He generally discovers this inability to drink accidentally, and often expresses his wonder that he should not be able to quench his thirst. The symptoms, once set in, rapidly increase in severity; any attempt to drink, and even anything that can suggest the idea of drinking, as the sound of liquid poured from one vessel into another, or the bright shining surface of polished metal looking like the surface of water, is sufficient to bring on the most frightful spasms of the throat, threatening instant suffocation, and producing the most severe pain. The convulsions, which were at first limited to the muscles of the throat and of deglutition, after a short time extend to other parts of the body; there is a constant agitation of the limbs, and a remarkable degree of nervous excitement; the patient is restless, anxious, and timid; his eye has a peculiarly unsteady glistening appearance, and he is often delirious, and talks with the greatest rapidity and earnestness to persons who are not present, or he thinks that his attendants are going to rob or murder him, and is haunted with frightful visions. As the disease proceeds, the convulsions of the throat become more frequent and severe; a breath of cool air, or the slightest noise or vibration of the room, is sufficient to excite them: there are severe headache, a rapid pulse, a foul tongue, and other symptoms of a generally disordered condition of the system. A copious secretion of thick tenacious mucus clogs up the air passages, and increases the feeling of suffocation, and it is in his attempts to free himself from this that the patient coughs and makes a loud harsh noise, which has been supposed to resemble the barking of the animal by which he was bitten. Sometimes there is furious delirium; but often for the last few hours of life the patient becomes quiet: he falls perhaps into a tranquil sleep, as if fatigued by his exertions, or he lies perfectly still, without spasms, and rational; but it is only a deceptive calm which presages his death; he rouses from his tranquillity, and, after one or two comparatively slight convulsions of the throat or of the whole body, expires. The duration of the disease is very rarely more than six days, and it often terminates fatally in twenty-four hours. In the latter cases the patient usually dies suffocated by one of the spasms of the throat; in the former he may have several remissions, in which the severity of the affection greatly decreases, and which may for a time seem to afford a hope of recovery. In most cases solids can be swallowed without much difficulty; and it is remarkable that in those who have been bitten by mad cats there is far less aversion to water than in those who have received the disease from the other species.

Nothing can at present be regarded as certainly known of the true nature of hydrophobia. Dissections of those who have died of it have shown the effects, but not the causes of its symptoms; as redness and turgescence about the throat and larynx, and general congestion from the frequent suffocative attacks. With this ignorance of its nature there is unfortunately an equal ignorance of any mode in which it may be treated with a prospect of success; for of all the medicines recommended (and probably no disease has been more variously treated) there is not one which has sufficient evidence to prove that it has been of the least avail, except in temporarily mitigating the symptoms. Opium in very large doses will produce quietude and great comfort to the patient by warding off the attacks of spasm, and will prolong, though it will not save life; and large bleedings have been useful in lessening the severity of the convulsions, and large doses of hydrocyanic acid have controlled the symptoms for days. But the only question that can be satisfactorily considered is that of prevention, which is accomplished by the removal of the morbid saliva from the wound before it has had time to produce its fatal influence on the body. Excision is at once the safest and most simple means, and whenever it is practicable should be employed as early as possible; the parts bitten should be completely cut out, with some of the sound tissues around them, and care should be taken that the very bottom of the wound is removed; for if a portion of the wounded surface remain, the patient is not secure. In some cases, however, as where the wound is superficial but extensive, or where it is situated on the face, or near an important organ, excision may be deemed unadvisable, and in these the best remedy is some violent caustic: pure nitric acid, or fused potash, or nitrate of silver, should be applied freely over the whole surface of the wound, so as to decompose every particle of the saliva. A third means is the careful washing of the wounds, but it is one on which it would be imprudent entirely to rely, though it should always be diligently employed until medical assistance can be obtained, and is useful after the parts have been cut out. The best mode of washing the wound is to pour water at a temperature of 90° or 100° on it, from a height of four or five feet, through the spout of a tea-kettle, and it should be continued for two or three hours, unless the other means are resorted to. It is not yet known at how late a period after the infliction of the injury it would be useful to remove the parts bitten; but considering the length of time during which the poison remains latent, and the probability that during that time it has only a local influence, it would certainly be prudent to remove the wounded parts after a lapse of even many days. Of course the value of these means is open to the objection already mentioned, that even when the patient does not suffer from hydrophobia it is uncertain whether his immunity depends on the measures employed; but it may be sufficient to state, that while every other remedy has frequently been unavailing, excision, when carefully employed, has been invariably successful, and the caustic has very rarely failed.

As a large majority of the cases of hydrophobia which occur in this country are the consequence of the bite of the mad dog, it may be useful to add the symptoms which he presents when in that state. He grows sullen and snarly; he leaves his home and runs about wildly, biting at whatever approaches him, though he will seldom go out of his way to attack, and he constantly gnaws grass and straws and pieces of wood or stone. To those, however, with whom he associates his demeanour is at first unaltered, and he caresses them as usual; and hence the cases in which death has followed the licking of a wound by dogs who showed no symptom of hydrophobia. It is an error to imagine that the mad dog avoids the water, for he will both drink it and swim in it as usual, and without presenting any of that horror of it which characterises the disease in man. Towards the close of the disease he grows more furious, gnawing and biting at everything around him, and frothing at the mouth. The disease is as incurable in the dog as in man, and usually lasts about the same length of time.

HYDROPS PERICARDII, or HYDROPERICARDIUM (from *ὕδωρ*, water, and *περικάρδιον*, the pericardium), is a collection of an unnatural quantity of fluid in the sac containing the heart. [Heart, Diseases of.]

HYDRORHODEORETIN. [Convolvulic Acid.]

HYDROSTATIC BALANCE. [Specific Gravity.]

HYDROSTATIC BELLOWS. [Hydrodynamics.]

HYDROSTATICS is the science which relates to the pressure and equilibrium of the fluids commonly called non-elastic, or incompressible, as water, mercury, &c., and to the equilibrium of bodies immersed in them. The elastic fluids, as air, steam, &c., are the subjects of pneumatics.

The two books of Archimedes, entitled, in Latin, 'De Humido Insidentibus,' contain all that is known concerning hydrostatics, properly so called, among the ancients. That philosopher showed from experiment that a mass of fluid will be in equilibrio when each of its particles is pressed equally in every direction. He explained that a floating body is held in equilibrio when its centre of gravity and that of the displaced fluid are in one vertical line; and that when bodies are immersed in a fluid of less specific gravity than themselves, they lose certain portions of their weights. The latter principle led him to the means of ascertaining the quantities of two different ingredients when mixed together in one mass; and he applied it in detecting the quantity of alloy in a golden crown which had been executed for the king of Syracuse.

The science of hydrostatics must, of course, be subject to all the laws of equilibrium of ordinary statics. [STATICS.] But there are two fundamental axioms which make it a distinct branch of that science, namely, (1), that *all* action between two fluid surfaces, or between a fluid and a solid surface, is *normal* to the plane in which they meet, that is, there is no such thing as *statical fluid friction*. This is the case, as far as we know, with all *perfect*, or non-viscous fluids. (2), That the amount of pressure at any point is independent of the *direction* of the surface pressed.

The cause of fluidity in bodies has been the subject of much discussion: it has been supposed to depend on the globular form of the particles, or on the caloric contained between them; or, finally, on both these circumstances combined. But, whatever be the primary cause, it is admitted by all that the property must arise, immediately, from the perfect mobility of the particles among one another; in consequence of which the mass immediately takes the figure of any vessel in which it is received, its upper surface assumes a level position, and by which, also, it begins to flow as soon as an orifice is made in any part of the sides or bottom of the vessel. Some difference exists however in the fluidity of different bodies: such as mercury, water, &c., which in their ordinary state possess this property in a high degree; while the particles of many fluids, as the oils, have a sensible adhesion to one another. With the exception of pure alcohol, all the non-elastic fluids, at certain temperatures, become congealed, and thus entirely lose their fluidity.

Since pores are known to exist between the particles of all bodies, fluid as well as solid, it may readily be conceived that no fluids can be absolutely incompressible: and experiments have been made from which it is manifest that spirit of wine, oil, water, and even mercury, can, by pressure, be reduced in volume, in certain degrees; the fluids which have the greatest specific gravity suffering the least compression. But as this diminution is very small when compared with the volume of the fluid (being for water, according to the experiments of Œrsted ('Trans. of Royal Society of Sciences at Copenhagen,' 1818 1822), only $46\frac{3}{10}$ millionths of its bulk for the pressure of one atmosphere, or about 15 lbs. on the square inch) for all practical purposes of hydrostatics such fluids may safely be considered as experiencing no change of volume by the compressions to which they may become subject.

Experiment has also shown that all the non-elastic fluids possess the property of transmitting equally in every direction the pressure exerted against any point on their surface. If, for example, a piston were forced into an orifice made in any part of the side of a vessel containing such a fluid, the effect of the pressure would be experienced equally at every point on the whole surface of the vessel. This property has hence been denominated the *quàquâversus* propagation of pressure; and it may be conceived to result from that perfect mobility of the particles among one another which has been above alluded to, and which enters into our first conception of fluidity.

But the pressure exerted by a fluid against the sides and base of a vessel in which it is contained, in consequence of a force thus partially applied, should be carefully distinguished from that which is caused by the gravity of the fluid: the former being the same in every part of the fluid mass, while the latter, at every point in the sides, depends on the depth of the point below the upper surface of the fluid.

It has been said above that a fluid in any vessel will have its upper surface in a level plane, or in a horizontal position; but it must be observed that, since the fluids on the earth are attracted towards the centre of gravity of the earth (leaving out the consideration of all disturbing forces, and considering the earth as a sphere), the particles must dispose themselves every way spherically about that centre; and consequently the upper part of a fluid in any vessel must be understood to form a portion of a spherical superficies concentric with that of the earth.

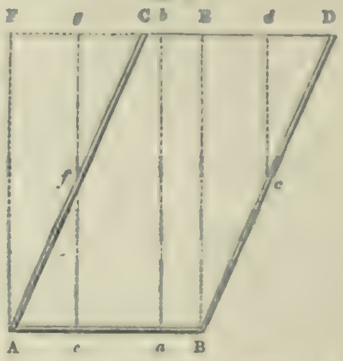
When, however, a mountain is near a sea, the level of the sea must be deflected somewhat upwards towards the mountain. If the Cordilleras, for example, were a hundred times higher than they are, the sea would slope upwards along the shores of America on both sides, and the ports of France and England, with those of Japan and China, would be left drained.

The quàquâversus pressure above mentioned has long since been proposed to be employed as a means of transmitting the action of a moving power to any distance, however great. For this purpose it has been projected to fill with water a horizontal tube having at each extremity a short arm in a vertical position; and in each of these arms to have a piston. Then that which is at one end of the tube having received the action of the moving power, it will, by means of the fluid, transmit the motion to the other; the rod of which should be in connection with the machinery on which it is intended to act.

From the same property it follows that if a fluid at rest in a vessel be supposed to consist of an infinite number of filaments, or infinitely slender columns in vertical positions, the pressure which, in consequence of the weight of the particles vertically above is exerted in every direction by any particle of such filament, will be counteracted by the equal pressure of all the surrounding particles, so as to remain at rest, and act by its gravity on the particle vertically under it. And that the pressure exerted by the fluid against every part of the surface of the vessel containing it, will, while the fluid is at rest, be perpendicular to the surface; since, otherwise, the reaction of the surface could not entirely destroy that pressure, and a part of it would disturb that equilibrium which, by hypothesis, is the condition of the fluid in the vessel. The amount of that reaction is, of course, equal to the weight of a filament of fluid vertically above the point and extending to the upper surface of the fluid; or to the weight of any one of the neighbouring filaments comprehended between the upper surface and a horizontal plane passing through the said point. The pressure of all the particles in the upper surface of the fluid is evidently null.

It may, hence, also be proved, that the pressure on the base of any vessel containing a fluid, will be the same whatever be the form or position of the sides of the vessel, provided the fluid have always the same height above the base. For let A B D C (*fig.* 1) be a vertical section through a prismatical vessel; the pressure on any point *a* of the base is evidently equal to the weight of the vertical filament *b a*; that on any point *c* of the inclined side B D is the weight of the filament *c d*; and this last produces no effect on the base, because the lateral pressures of all the particles in every vertical filament, are counteracted by those of the particles in the neighbouring filaments. The same thing must be understood of all the water in the portion E B D. The pressure on any point *e* under the inclined side A C is equal to the weight of the filament *e f*, together with the pressure arising from the reaction of the side A C at *f*, in the vertical direction *f e*; and this reaction is, from what has been said, equal to the weight of a filament which may be supposed to exist above *f*, with a height equal to *f g*. Consequently, the pressure on A B, when the sides of the vessel are inclined to the horizon, will be equal to that upon the same base when the sides are in vertical positions. This is the foundation of the experiment usually exhibited in popular lectures, when columns of water of equal height, in cylindrical and conical vessels, having equal bases, but of course containing very different quantities of the fluid, are shown to be in equilibrio with one and the same weight applied to prevent the moveable bases from descending.

Fig. 1.

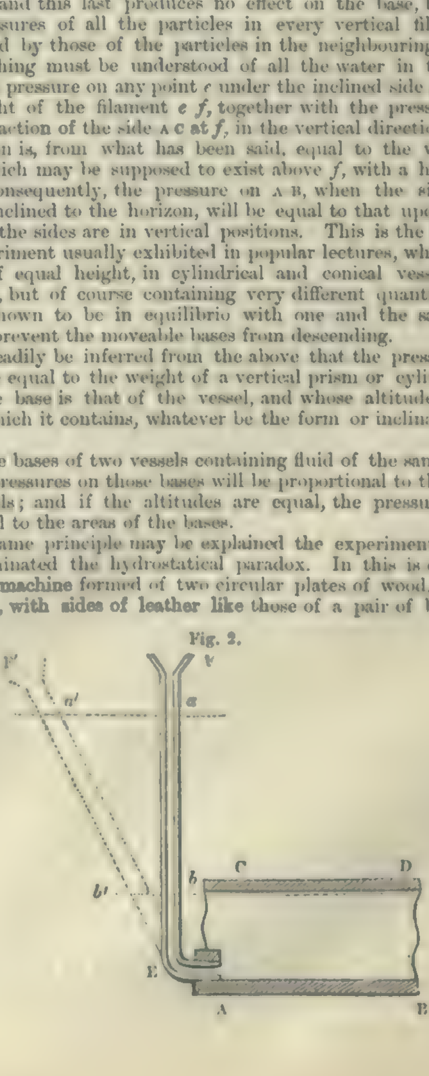


It may readily be inferred from the above that the pressure on the base will be equal to the weight of a vertical prism or cylinder of the fluid, whose base is that of the vessel, and whose altitude is that of the fluid which it contains, whatever be the form or inclination of the sides.

When the bases of two vessels containing fluid of the same kind are equal, the pressures on those bases will be proportional to the altitudes of the fluids; and if the altitudes are equal, the pressures will be proportional to the areas of the bases.

On the same principle may be explained the experiment which has been denominated the hydrostatical paradox. In this is employed a cylindrical machine formed of two circular plates of wood, as A B and C D (*fig.* 2), with sides of leather like those of a pair of bellows. A

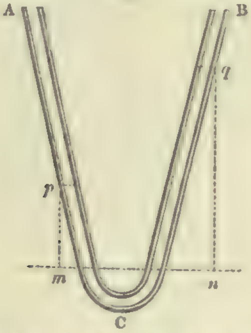
Fig. 2.



tube F E is inserted in an orifice near the bottom, and through this tube water is poured into the cylinder, till the boards A B and C D are at any distance asunder within the limits allowed by the leathern sides. Then, if any weight be placed on the board C D, it will cause the water to rise in the tube E F to a certain height, suppose a; and the weight of the small column $a\,b$ of water may be considered as holding in equilibrio the weight applied on C D; which will, in fact, be found to be equal to that of a cylinder of water whose base is the area of the board C D, and whose height is equal to $a\,b$.

If the tube E F were made to decline from the vertical so as to take any oblique position E F′; it would follow, since the pressure of a fluid by gravity depends on the vertical height only of the column, that the fluid in the tube, from the same pressure on C D, would rise till its upper surface is in a horizontal plane $a\,a'$ passing through a: and the weight of the column of fluid must be estimated by the area of the horizontal section at b' multiplied by the vertical height of a' above b'. Hence, also, any fluid in a bent tube A C B (*fig.* 3) will stand in each branch, the tube being open at both ends, at the same vertical height above C, the lowest point. Thus water, which is conveyed in pipes from a reservoir, will occupy all the bends of the pipes, and rise at the further extremity up to a horizontal plane passing through the surface of the water in the reservoir, provided no vertical bend be higher than that level.

Fig. 3.



The power produced by the Hydraulic Press depends on the principle exhibited in the above experiment; and this experiment is, at the same time, the proof of that equality of pressure which it has been said that the particles of a fluid exert in every direction.

The pressure exerted by a fluid against the whole side of a vessel containing it, or against a surface immersed in it, whether that side or surface be plane or curved, is equal to the weight of a column of the fluid having the surface pressed for a base, and the distance of the upper surface of the fluid from the centre of gravity of the former surface for its altitude. For let D B (*fig.* 1) be the position of the surface pressed, and let an indefinitely small area at c on that surface be represented by m, and be pressed by the weight of the filament $c\,d$ of fluid above it; then, since every part of the indefinitely small area may be supposed to be at the same vertical depth, which may be represented by n, it follows that the pressure on c will be proportional to $m\,n$. And the same thing will hold good with respect to every point in the surface D B. Therefore this surface may be conceived to be pressed by an infinite number of parallel forces, whose points of application are on the same surface, and whose intensities are represented by the products of the elementary areas into the distances of those areas from the upper surface C D of the fluid. But, by the theory of parallel forces in mechanics, the resultant of all those forces is a force whose intensity is represented by the sum of all the elementary areas (that is, the area of the surface pressed) multiplied into the distance of its point of application, that is, of the centre of gravity of the surface, from the same surface C D. By this theorem the pressure of water against the walls of reservoirs, lock-gates, &c., may be determined.

The pressure against one side of a cubical vessel filled with a fluid is equal to half the pressure upon the base; for the areas of the base and of each side are equal to one another, but the centre of gravity of the former is at a distance from the upper surface equal to the whole depth, and that of the latter at a distance equal to the half depth. It is shown moreover in treatises on hydrostatics, that if a hollow cone standing on its base be filled with a fluid, the pressure on the base will be equal to three times the weight of the fluid; that the pressure against the interior surface of a hollow sphere filled with a fluid is also three times the weight of the fluid. Again, if a vessel of any figure be full of a fluid, and have over every part of the sides and bottom a vertical filament of the fluid reaching to the upper surface, the whole pressure in a vertical direction on the bottom and sides of the vessel will be equal to the weight of all the fluid. Lastly, the pressure exerted on the sides of a vessel, estimated perpendicularly to the base, is equal to the weight of a rectangular prism of the fluid whose height is equal to that of the fluid, and whose base is a parallelogram, one side of which is equal to the height of the fluid, and the other to half the perimeter of the vessel. (Vince's 'Hydrostatics;' Gregory's 'Mechanics,' &c.)

It is of importance to determine the place of the centre of pressure against the side of a vessel filled with a fluid, or against a surface which is immersed in it; that is, to find the situation of a point in that surface, at which a force being applied in a contrary direction to that in which the fluid presses, the surface will be kept in equilibrio.

Let, for simplicity, the side or surface pressed be rectangular, and in a vertical position; let, also, b represent the breadth, and a the altitude of the surface, or depth of the fluid: then $\frac{1}{2}a$ will be the depth of the centre of gravity below the upper surface of the fluid. Now if x be the distance of any elementary area of the side below the same upper surface, such elementary area will be expressed by $b\,d\,x$; and the pressure of the fluid against it being proportional to the depth, will $= b\,x\,d\,x$. Then the tendency of that pressure to turn the side of the vessel round, about its upper extremity, which is supposed to be a horizontal line, will be $b\,x^2\,d\,x$; consequently the whole tendency of the fluid to turn the side round in that manner will be expressed by $\int b\,x^2\,d\,x$, which between the limits $x = 0$ at the top, and $x = a$ at the bottom, is equal to $\frac{1}{3}\,b\,a^3$. But, if P be the required place of the centre of pressure, and its distance from the upper surface of the fluid be represented by p, the tendency of the same pressure applied at P to turn the side about its upper extremity, will be $\frac{1}{2}\,a^2\,b\,p$ ($\frac{1}{2}\,a^2\,b$ being the horizontal pressure of the fluid against that side). Therefore we have $\frac{1}{3}\,a^3\,b = \frac{1}{2}\,a^2\,b\,p$, or $p = \frac{2}{3}\,a$; that is, the centre of pressure is at a distance from the upper surface equal to two-thirds of the depth of the vessel or fluid. And, by writers on hydrostatics, it is proved that, in all cases, when the surface pressed is symmetrical on each side of a line joining the centres of gravity and pressure, the latter coincides with the centre of percussion in mechanics.

When a triangle in a vertical position is immersed in a fluid so that its vertex coincides with the upper surface of the fluid and its base is horizontal, the distance of the centre of pressure from the vertex is equal to three-fourths of the perpendicular of the triangle. And when a circle is so placed in a fluid with its upper part just touching the surface, the distance of the centre of pressure from that part is equal to five-eighths of the diameter.

The equality of the pressures in every direction, at any point in a fluid mass, is the cause that, if a solid body be plunged in a fluid, the pressure of the fluid immediately under it will tend to raise the body upwards with a force equal to the weight of the fluid displaced. But the weight of the body is a force acting vertically from above downwards; and, consequently, in an opposite direction to that caused by the reaction of the water. Since therefore the volumes of the body and of the displaced water are equal to one another; if their weights or densities should be equal, the body would remain in equilibrio in whatever situation it were placed in the fluid. But should these weights or densities be unequal, the body would make an effort to ascend or descend, according as its density is less or greater than that of the fluid; and, in order to counteract these tendencies, it would be necessary to use a force equal to the difference between the weight of the body and of the displaced fluid. Hence, if a solid body be weighed in a fluid, it will be found that its weight, compared with that of the same body in vacuo, will be less than in the latter case by the weight of an equal volume of the fluid; and, consequently, when a body is weighed in a fluid, as water or air, the true weight, or that which would be obtained in vacuo, will be found by adding to the observed weight that of an equal volume of the fluid.

When a body floats in a fluid, in order to bring its upper surface to coincide with that of the fluid, it must evidently be loaded with a weight equal to the difference between the weight of the body or of the displaced fluid, and the weight of a volume of the fluid equal to that of the whole body. The weight which a floating body will thus bear is denominated the buoyancy of the body; and on the principle here stated depend the common rules for finding the buoyancy of rafts, vessels, &c.

If a solid body float in equilibrio in a fluid, the centres of gravity of the body and of the displaced fluid must evidently be in one vertical line; otherwise the upward action of the fluid below, which necessarily has its resultant in a vertical line passing through the centre of gravity of the place occupied by the body, would produce in the latter a rotatory motion contrary to the hypothesis. This circumstance has given rise to three denominations respecting the equilibrium of floating bodies. First, if the centre of gravity of the body should be below that of the displaced fluid, the body is said to possess a stable or firm equilibrium; so that if any derangement should take place from accidental causes, the body would, after a few oscillations, recover its former position. If the centre of gravity is above that of the displaced fluid, the body is in circumstances similar to those of a cone when placed on its vertex, that is, it is liable to be immediately overturned; and hence the body is said to float with a tottering or unstable equilibrium. And if the said centres should exactly coincide, the body would float in any position whatever: this is denominated an equilibrium of indifference. The first case is that of a cylinder whose axis is less than the diameter of its base; the second is that of a cylinder whose axis is greater; and the last is that of a homogeneous sphere.

The absolute weight of a given volume of any solid or fluid body is called its specific gravity. In this country, for convenience, it is customary to consider one cubic foot as the given volume, and to express the weight in avoirdupois ounces: thus the weight of a cubic foot of rain water being 1000 ounces, and that of a cubic foot of cast-iron being 7207 ounces, those numbers are used to denote the specific gravities of the bodies. From this definition it follows that, when the volumes of two bodies are equal, their specific gravities will be proportional to their weights: when the weights are equal, the specific gravities are inversely proportional to the volumes; and, in general, the weights of bodies vary in a ratio compounded of their volumes and specific gravities.

It may hence be easily shown that when two fluids of different specific gravities, as water and mercury, are in equilibrio in a bent tube, the vertical altitudes of the columns above the horizontal plane of junction will be inversely proportional to their specific gravities. For, let m n (*fig.* 3) be a line in the plane of junction; then the area of the section at m being common to both fluids, the bases of the columns in the two branches may be considered as equal to one another. Now, if the vertical altitude of the column m p be represented by a, and that of n q by A, the specific gravity of the fluid in m p by S, and that in n q by s; then the weights of the columns, or rather the pressures on every point of their bases, at m and n may be expressed by a S and A s; and in the case of equilibrium these terms are equal to one another: therefore we have A : a : : S : s.

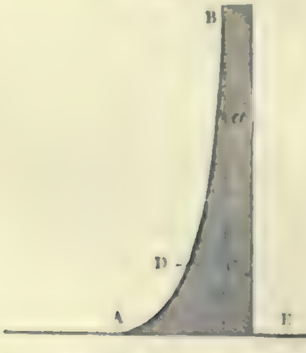
The specific gravity of a solid body is readily found by means of the hydrostatical balance, an instrument which differs in no respect from a common balance, except in being made with greater delicacy. It is customary to weigh the body both in air and in vacuo; from whence may be obtained the ratio between the density of the body and that of the fluid in which it is weighed. [Specific Gravity.]

The specific gravity of a fluid may be found from the following proposition: let $a+b$ be the volume of a body which will float in the fluid, b being that of the immersed part; let also the specific gravities of the body and fluid be represented by s and s' respectively. We have then the weight of the body $=(a+b)\,s$, and that of the displaced fluid $=b\,s'$; but these weights are equal to one another: therefore, $b:(a+b)::s:s'$. Consequently, the specific gravity of the solid body being supposed to be known, we have that of the fluid, after making a correction on account of the loss of weight in air. On the principle explained in this proposition is founded the construction of the **Hydrometer**, by which the qualities of liquors are usually determined.

By means of the specific gravity of bodies may be ascertained the quantities of the different materials which enter into any compound body. Thus, let w and w' represent the weights of a mixed metal in air, or vacuo, and water respectively, s and s' the known specific gravities of the two metals in the mixture, and let x be the weight in air or vacuo of the heavier metal. Then $\frac{x}{s}=$ the weight of water which would be displaced by x; $\frac{w-x}{s'}=$ the weight which would be displaced by the lighter metal; and we shall have $w'=\frac{x}{s}+\frac{w-x}{s'}$; whence $x=\frac{s\,(w-w's')}{s-s'}$, and $w-x$ (= the weight of the lighter metal) $=\frac{s'\,(w'-w\,s)}{s-s'}$.

It has been shown that the pressure of a fluid against any point in an upright wall, or in the side of a vessel containing it, is proportional to the depth of that point below the upper surface of the fluid; but, in determining the form and dimensions of a retaining wall which shall be equally strong in every part of its height, it will be necessary to consider that the horizontal pressure of the fluid at any point, as a (*fig.* 4) (B A E representing a vertical section through such a wall), tends to overturn or fracture the wall at every other point, as C. Now, let B $a=x$, and let the depth of an elementary portion of the wall at a be represented by $d\,x$; then, if B C be represented by b, we shall have C $a=b-x$, and $(b-x)\,x\,d\,x$ will express the force of the water on an elementary area at a to turn the wall about C: consequently, $\int(b-x)\,x\,d\,x$, between $x=0$ and $x=b$, will express the sum of all the forces of the water above C to turn the wall about the latter point. But the integral between those limits is equal to $\frac{1}{6}\,b^3$: therefore the tendency of the fluid to fracture the wall at any point, as C, is proportional to the cube of the distance of that point from the upper surface of the fluid. The strength of the wall to resist transverse pressure in the direction of its thickness is, by mechanics, proportional to the square of that thickness; that is, proportional to C D^2. Therefore, in order that the wall may be equally strong in every part, the form of a vertical section should be such that the squares of the horizontal ordinates, as C D, are proportional to the cubes of their vertical depths from the top. This is a property of the semi-cubical parabola, and the exterior or interior surface of the wall should have that figure. Agreeably to this principle also the thickness of tubes containing columns of fluid in vertical positions should increase from top to bottom, according to the same law.

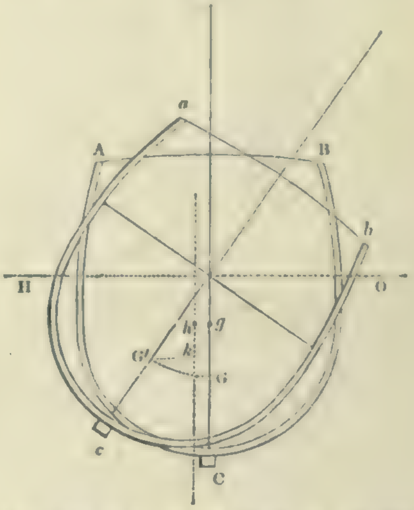
Fig. 4.



This article may be concluded by an indication of the principles on which the stability of ships or other vessels on the water may be determined.

Let A B C (*fig.* 5) represent a vertical section through the centre of gravity G of a ship, and let H O be the surface of the water; let also g be the centre of gravity of the immersed part, while the plane of the masts is vertical. Now, by the action of the wind or otherwise, let the ship be inclined so as to take the position $a\,b\,c$; the centre of gravity of the immersed part and of the displaced water will then be removed to h, and that of the ship to G′. Draw a vertical line through h, and let fall upon it the perpendicular G′ k; then the stability of the vessel, or the force by which it resists the effort of the wind to overturn it, is expressed by the product of the upward pressure of the water (or the weight of the vessel) acting in the vertical line $k\,h$ into the length G′ k of the lever, whose fulcrum is G′. And, that an equilibrium may subsist, this expression must be at least equal to the product of the force of the wind acting against the sails or hull into the distance of the centre of pressure, or *metacentre*, from the centre of gravity of the ship.

Fig. 5.



Hence it is, that the keel and bottom of a vessel must be made so much stronger, the deeper the vessel sinks. Suppose a vessel sinks 16½ feet when loaded; then the bottom must be able to resist a pressure of 7¼ lbs. on the square inch, that is, the weight of a cylinder of water 16½ feet long, and 1 inch in section. Hence, if a leak should spring in such a vessel, a weight of 7¼ lbs. per square inch would be required, to keep a plank, thrown across the hole, from being forced upwards.

HYDROSULPHOCYANIC ACID. [Cyanogen.]

HYDROSULPHURIC ACID. [Sulphur; *Sulphuretted Hydrogen.*]

HYDROTHIONIC ACID. Synonymous with *Sulphuretted Hydrogen.* [Sulphur.]

HYDROTHO'RAX (from ὕδωρ, water, and θώραξ, the chest), dropsy of the chest, is a term applied to express the existence of a collection of serous fluid in the cavity of the pleura.

This collection may take place in consequence of inflammation of the pleura, which, like inflammation of other serous membranes, terminates in effusion; or it may result from the causes of general dropsy,—namely, some obstacle to the circulation through the heart, or organic disease of the kidney. When it arises from the former cause it is merely a symptom of pleurisy. In some cases of pleurisy, however, in which pain is absent, and in which fever does not exist, or is slight, this effusion and the difficulty of breathing to which it gives rise constitute almost the only symptoms of the disease. Abundant effusions of this kind, unattended by pain or fever, sometimes take place very rapidly, especially in old persons and in adults in a cachectic condition.

When hydrothorax results from inflammation of the pleura, it generally exists on one side only of the chest. When it is a consequence of obstacle to the circulation through the heart, or of organic disease of the kidney, it is generally double, although the effusions into the two pleural cavities may not take place quite simultaneously. In the latter case, also, hydrothorax is found in connection with general dropsy. At first there is œdema of the lower extremities; this œdema gradually extends to the integuments of the trunk, to the arms, and even to the face; and, subsequently, serous fluid is effused into the cavities of the pleura, giving rise to hydrothorax, and into those of the pericardium and peritoneum.

A collection of fluid in the cavity of the pleura may be detected by physical signs: a dulness on percussion, and, when the effusion is moderate, a diminution of the respiratory murmur, and the presence of ægophony, on the affected side. If the effusion be so considerable as entirely to prevent the expansion of the lung, there is a total absence of ægophony or of any respiratory murmur on that side, whatever be the force with which inspiration is made, while on the opposite side the respiratory murmur is unusually audible.

When one side only is affected, the patient generally lies on that side; when the effusion is double, he lies on his back; or, which is the case when the effusion is considerable, he can breathe in the erect position only. The difficulty of breathing is generally greater in proportion to the rapidity with which the fluid is effused. [PLEURITIS.]

HYDROTIC ACID. [SUDORIC ACID.]

HYDRURETS. [HYDROGEN.]

HYDRUS (constellation), the Water-snake, commonly called the Southern Snake, a constellation of Lacaille. It is situated between the south pole and the bright star in Eridanus (Achernar).

Character.	No. in Catalogue of Lacaille.	No. in Catalogue of British Association.	Magnitude.
η^2	595	603	4
α	605	623	3
δ	747	756	4

HYGIEIA (Ὑγίεια), the goddess of health, called also Salus by the Romans, was the daughter of Æsculapius, with whom she was frequently associated in worship, both by the Greeks and Romans. She was worshipped as the goddess of both mental and bodily health, and in some of her attributes resembled Athena, one of whose titles was Athena Hygieia. Representations of Hygieia, both alone and with her father, are very numerous in ancient art. She appears always as a virgin of beautiful form, and pleasing expression, and is clad in a long full robe. Most frequently, she is giving drink to a serpent from a patera which she holds in her left hand. The annexed cut is from a terra-cotta bas-relief in the British Museum.

Hygieia from the British Museum.

HYGRO'METER (ὑγρός, moist, and μέτρον, measure). In physical experiments it sometimes becomes necessary to ascertain the quantity of aqueous vapour contained in the atmosphere or other aëriform fluid under examination. To attain this object several instruments called hygrometers have been invented, and are known by the names of their authors, as De Luc's, De Saussure's, &c. These for the most part rest upon one common principle, the diminution of bulk which takes place in organic tissues consequent upon the abstraction of moisture. Thus De Luc employed a thin slip of whalebone, the contractions of which indicated the variations of moisture; and De Saussure had recourse to a human hair, by means of which he constructed a far more delicate instrument; but this was exceedingly liable to derangement, and unless prepared with extraordinary care was uncertain. All of these, however, were nearly superseded by the hygrometer invented by the late Mr. Daniell, professor of chemistry at King's College, London, first described by that gentleman in 1819, in the 8th volume of the 'Quarterly Journal of Science;' subsequently in his 'Meteorological Essays,' and in his posthumous work on 'Meteorology.' It consists of two thin glass balls one inch and a quarter in diameter, connected by a glass tube about seven inches in length. The tube is bent in two places at right angles so as to form three arms of unequal length, the longest of which contains a small thermometer, whose bulb descends into the lower of the two glass balls. This ball, after being filled about two-thirds with ether, is placed over a spirit-lamp until the vapour of the ether has expelled the contained air through a capillary tube which is left open for the purpose, and afterwards hermetically sealed. The other ball is then covered with a piece of muslin, and the instrument thus adjusted is placed upon a stand, to which is attached a small thermometer indicating the temperature of the external air. When about to be used a small portion of ether is poured upon the muslin, which, by evaporating, lowers the temperature of the glass ball, and thereby occasions a rapid condensation of the ethereal vapour contained within the instrument. The condensation of the vapour within the tube produces a continuous evaporation from the surface of the ether in the lower ball, by which the temperature of the included ether is continually reduced until a deposit of moisture from the surrounding atmosphere is observed to take place upon the exterior of the glass. At this instant the inner thermometer, which always indicates the temperature of the ether, is observed, and thus the dew point, or that at which the precipitation of atmospheric moisture takes place, is determined with considerable accuracy. Having ascertained the dew point, and likewise the temperature of the external air, the actual quantity of moisture contained in a cubic foot of air will readily be found from the formula,

$$\text{Weight in grains} = \frac{5656{\cdot}2}{448 + t} \times p,$$

where t denotes the temperature of the external air, and p the elasticity of aqueous vapour at the temperature indicated by the interior thermometer. The value of p for every degree of the thermometer is given in Mr. Dalton's tables of the expansive force of steam. ('Manchester Memoirs,' v. 559.)

But this instrument, so excellent in theory, is very costly on account of its great consumption of ether, and is scarcely useable in hot climates, owing to the difficulty of preserving that liquid. It has also been objected to by competent authority, because *an experiment* has necessarily to be made to obtain an observation. At the Royal Observatory at Greenwich, however, it appears to have been employed for the determination of the dew-point from the commencement of the meteorological observations in the year 1840 until the end of 1847, since which, to the present time, that element has been exclusively inferred in those observations from the simultaneous reading of two thermometers, the bulb of the one being dry and the other wet, agreeably to the method which has now almost universally superseded every other, and which is explained in the next article.

Under the head DEW, some experiments of Dr. Wells and of Mr. Glaisher have been noticed, having an important bearing upon the use of many inorganic as well as organic substances for hygrometrical purposes, as well as upon the necessity of screening hygrometrical apparatus from the effects of its own nocturnal radiation.

HYGROMETRY is that part of natural philosophy which relates to the determination of the humidity of bodies, particularly of the atmosphere: it comprehends also the theory of the instruments noticed in the preceding article, which have been invented for the purpose of ascertaining the quantity of water contained in a given volume of air.

The experiments of Dr. Dalton have proved that the water received from the earth is not dissolved in the atmosphere, and that it exists there in the state of vapour, and forming, statically, a distinct atmosphere from that of the air, though coexisting with it in the same space. That philosopher discovered also, that the quantity of vapour contained in a portion of the atmosphere depends greatly upon the temperature of the latter, and that it is very variable even when the temperature is constant. He ascertained moreover that when a quantity of aqueous vapour at a given temperature is diffused through any space, it will support the same external pressure, whether previously that space had been void or occupied by air. On these principles are founded the methods which have been used for determining the absolute quantity of moisture in a given volume of air by means of the hygrometer: the requisite data being the elasticities of aqueous vapour at different temperatures, and the corresponding indications of the instrument.

The tension or elasticity of watery vapour corresponding to every degree of Fahrenheit's thermometer, from zero to the point of boiling water (measured by the height in inches of the column of mercury which the vapour will support when the density of the atmosphere is represented by 30 inches), has been determined by Drs. Dalton and Ure, who for this purpose introduced a small quantity of water into the vacuum of a barometer, and observed how much, at different temperatures, the vapour arising from it depressed the column of mercury; and tables of such tensions are published in the fifth volume of the 'Manchester Memoirs,' and the 'Philosophical Transactions' for 1818.

Previously to stating the manner of determining the relation between the indications of an hygrometer and the state of aqueous vapour with respect to tension, it will be proper to notice the following circumstances:—When an hygrometer, like that of Saussure or De Luc is introduced into a close vessel, or into any part of space fully saturated with aqueous vapour, it is observed that, whatever be the temperature, the index points to the same degree; from which it may be inferred that equal quantities of vapour have been absorbed by the material (hair or whalebone) of which the instrument consists, notwithstanding the difference of temperature. In fact the vapour in the vessel, or space, is in such a state that the presence of a material having the least possible attraction for water is sufficient to produce a precipitation of the latter: the hygroscopic material has an attraction for water, and thus it absorbs that which is precipitated. But the quantity absorbed is so small as not to diminish sensibly the elasticity of the vapour in the vessel; and therefore the absorption continues to the full extent of the attraction of the material: the quantity thus absorbed is necessarily constant, unless the attraction undergo some change by a change of temperature; but experience proves that the attraction of the material is not sensibly altered by such change within the usual limits of the thermometric scale.

When the vessel into which the hygrometer is introduced is not completely saturated with water, the quantity of water absorbed by the hygroscopic material is limited by the power of the latter to absorb the precipitated moisture: that power diminishes in proportion to the quantity received, so that the attraction of the material for water ceases to act when it is equivalent to the pressure which the vapour can support without becoming liquid; and the elongation of the hair or whalebone then ceases, or the index remains stationary on the scale.

In order, then, to determine the law according to which the attraction of the hygroscopic material for water diminishes as the precipitated water is absorbed by it, or, in other words, to find on the scale of the hygrometer a number of points corresponding to any given elasticities of the vapour, Gay Lussac put water into a vessel of glass; and, having determined the elasticity of the vapour arising from it, he suspended from the upper part of the vessel a delicate hygrometer of the kind invented by Saussure. The vessel was then closely covered, so that there might be no communication between the vapour within and the external air; when, after a short time, the index of the hygrometer became stationary at a certain point on the circumference of the graduated ring which served as a scale; this point thus became an indication of the elasticity of the vapour. Experiments of the like kind being made with vapour of equal temperature, but in different states of elasticity, between those which correspond to extreme dryness and complete saturation, there were obtained so many points on the scale of the instrument as indications of the elasticities of the vapour.

From the results of these experiments, M. Biot found, by interpolation, a table of the elasticities of vapour for every degree of Saussure's hygrometer, the temperature being 10° of the centigrade thermometer (50° Fahr.). He also formed a table showing the degrees of the hygrometer corresponding to every degree of elasticity. The extremes of dryness and moisture on the scale, and also the corresponding extremes of elasticity, were indicated respectively by 0 and 100 (Biot, 'Traité de Physique,' liv. i. ch. 13); but the elasticities or tensions would be more conveniently expressed in terms of the elasticity at the point of complete saturation, which is then represented by unity.

The numbers in the table are formed from the observed tensions at a constant temperature equal to 50° (Fahr.); and it might be supposed, since the index of the hygrometer stands constantly at 100° when the material is acted on by vapour in the state of maximum tension whatever be the temperature, that the index should stand at one point on the scale when the tensions of the vapour have the same proportion to the maximum tension at their respective temperatures: this supposition is not quite correct; but it may be presumed that in using Biot's table for temperatures differing from 50° Fahr., the error in the tensions will not be considerable.

Gay Lussac having proved that vapours, whether those of pure water or those of different liquids intermixed, while they retain their character of elasticity, suffer the same variations of volume by variations of pressure as are suffered by fluids, which are permanently elastic within ordinary ranges of temperature and pressure, determined, by subsequent experiments, the volumes of the vapour produced by a given weight of water at given temperatures and under given atmospherical pressures; and thus, consequently, obtained the quantity of moisture in a given volume of vapour. The results of his experiments were reduced to a formula by Biot; and subsequently, with certain modifications, to one in English weights and measures by Dr. Anderson, the writer of the article on Hygrometry in the 'Edinburgh Encyclopædia.' This formula is

$$G = \frac{10953\,B\,.\,F}{447{\cdot}4 + t};$$

in which G is, in grains, the quantity of moisture in a cubic inch of vapour at the temperature represented by t (Fahrenheit's scale), F is the elastic force of the vapour at the same temperature, and B is the height of the barometrical column in inches at the time of the experiment.' It agrees nearly with that which was obtained by Dalton from experiments on the state of the thermometer at the dew-point, the height of the mercurial column in that result being 30 inches. From this formula, the temperature t being 50° (Fahr.), $B = 30$ inches, and $F = 0{\cdot}375$ (from Dalton's table of the elastic force of vapour corresponding to that temperature and that density of the air), we have $G = {\cdot}002477$, the grains of moisture in a cubic inch of the vapour.

The value of G being thus found for any given states of the barometer and thermometer; the weight of moisture, in grains, in a cubic inch of air of the like density and temperature, and corresponding to any observed degree of Saussure's hygrometer may be obtained on multiplying that value by the number in Biot's table corresponding to the observed degree and dividing the product by 100; this division must be made because, in that table, 100 represents the elasticity of the vapour when in the state of complete saturation.

The extreme points on the scale of an hygrometer acting by the elongation of a material, like those of Saussure and De Luc, may be found in the following manner: the instrument is to be placed under a receiver in which is a certain quantity of dry caustic alkali; when, after a time, the material will contract in length as much as its nature will permit; the point on the scale at which the index stands is that of extreme dryness, and constitutes the zero point. The instrument may then be placed in water, or in a receiver filled with vapour completely saturated with moisture, when the material will expand to the greatest extent possible: the place of the index is then to be considered as the point of extreme humidity, and is usually indicated by 100. The employment of organic substances in hygrometry, has however, been long since almost disused, for exact purposes.

Leslie's hygrometer consists of a glass tube bent so as to form two equal branches parallel to one another, and each terminating with a hollow ball into which is introduced sulphuric acid, coloured. One of the balls is covered with cambric, which is kept constantly moist by water from a neighbouring vessel; and the evaporation of the water, by cooling that ball, allows the air in the other, by its superior elasticity, to depress the acid in the tube below and force it to rise in the other. The degree of evaporation depends partly on the temperature, and partly on the state of the surrounding atmosphere with respect to humidity; and hence the depression of the acid in the tube, being measured by a convenient scale, affords an indication of the relative dryness of the air. In order to determine the absolute quantity of moisture in a given volume of the atmosphere by the state of his hygrometer, Leslie, having found from some experiments that the capacity of air for caloric was $\frac{3}{8}$ of that of water, and having ascertained that the quantity of caloric necessary to convert a given volume of water into vapour was expressed by 6000 degrees of his instrument; concluded that the same quantity of caloric would raise an equal volume of air to a temperature expressed by $\frac{8}{3} \times 6000$, or 16,000 degrees of the instrument; and consequently that, at the temperature of the wet ball, atmospheric air contains a quantity of moisture equal to $\frac{1}{16000}$ part of its weight for each degree; the scale between the points of extreme dryness and extreme moisture being divided into one thousand parts. (Treatise 'On the Relations of Air to Heat and Moisture.')

From the fact that the elastic forces of pure vapour and of vapours mixed with atmospheric air are equal to one another, the expansion which air undergoes in consequence of being saturated with moisture may be found. For if V represent a given volume of dry air, V' the volume when saturated, and B, in inches, the height of the barometrical column; then the elastic force of the air, under the increased volume V' is $\frac{V.B}{V'}$. Now F representing the elastic force of the vapour in inches of mercury, which, for the given temperature, may be found from Dalton's table, the sum of the elastic forces of the air and vapour will be expressed by $F + \frac{V.B}{V'}$; and this being made equal to B, the pressure of the atmosphere, the value of $V' - V$ may be found. Making $V = 1$, that value expresses the expansion in a fractional part of the volume of dry air.

At any place on the surface of the earth, the mean temperature at which moisture begins to form in the atmosphere may be found from Dalton's formula $E = \frac{1}{30} M (F - F')$, in which E is the number of grains evaporated in one minute from the surface of water in a cylindrical vessel 6 inches in diameter and 1 inch deep, F is the elastic force of vapour in the atmosphere at a given temperature, which may be the mean annual temperature at the place (50° Fahr., for Great Britain), and F' the elastic force exerted at the time that the moisture begins to form: M is, in grains, the evaporating force in an atmosphere supposed to be perfectly dry; and Dalton has given a table of such forces for different temperatures, the atmosphere being at rest, in gentle, and in violent motion. In the table, the temperature being 212°, the height of the barometrical column 30 inches, and the wind blowing moderately, the value of M is 154; and substituting this value in the formula, we have $F' = F - \frac{1}{5} E$.

The mean annual evaporation in Great Britain is ·0000456 inches or ·01155 grains per minute: this last number being multiplied by the area of a circle 6 inches in diameter, gives 0·3236 grains per minute ($= E$) from a vessel of that magnitude; hence $F' = F - 0{\cdot}0647$. But, by Dalton's table, the elastic force (F) of vapour at a temperature equal to 50° is expressed by 0·375, in inches of mercury; hence $F' = {\cdot}3103$ inches. Substituting in the above formula for G this value of F' in place of F, and 30 inches for B, we get ·00205 for the number of grains of moisture in a cubic inch of air corresponding to the elasticity F′. To this number corresponds the temperature 44° 16′; which may be found by inspection in a table formed to contain the values of G for different degrees of temperature.

The subject of hygrometry, including the principle and construction of the numerous instruments which have been employed for the purpose of determining the amount and tension of aqueous vapour in the air under various circumstances, has formed, during a century past, so considerable a part of meteorology and experimental physics—especially from the time of the publication of a celebrated paper by De Luc, in the 'Philosophical Transactions' for 1792—and is so intimately connected also with the history of the progress of science in that period, that we have thought fit to retain, with a few slight insertions and alterations, the preceding portion of this article as it originally appeared in the first supplement to the 'Penny Cyclopædia,' in the year 1846. But it has already been remarked, in the article DEW-POINT, that for the determination of that critical temperature and its depression, the *indicia* of all hygrometry, the simultaneous observation of the dry-bulb and the wet-bulb thermometer is now almost universally adopted, according to a method we shall proceed to describe.

In this method the bulb of the wet thermometer, as described by Mr. Glaisher in the Introduction to the 'Greenwich Meteorological Observations' for 1847, is covered with a piece of fine muslin; immediately under it is placed a small cistern of rain-water. A piece of cotton lamp-wick is connected with the muslin, and its end dips into the cistern of water; the water ascends the wick by capillary action, and keeps the muslin on the thermometer constantly wet. In frosty weather the muslin is moistened for a sufficient length of time before each observation, in order to allow the water to have become frozen, and the evaporation from the surface of the ice to have commenced, at the time of making the observation; the evaporation of the ice will depress the temperature, as if it had remained liquid. These thermometers should be placed and observed in such a locality as shall afford the best chance for procuring a fair indication of the moisture of the general atmosphere, and by no means in any confined or ill-ventilated situation, or where many persons habitually congregate, or which, from any other cause, is usually or periodically damp. The whole apparatus should be protected by a cap of wire-work to defend it from injury, which, however, if it interfere with the readings of the thermometer, should be removed a quarter of an hour before the observation. At night the thermometers should be completely screened from the sky, so as to annihilate all loss of heat by upward radiation.

The dry thermometer is to be first read, and in reading it, as in all readings of such instruments, the observer should avoid touching, breathing on, or in any way warming it by the near approach of his person; and in night observations particular care should be taken not to heat it by approach of the light. The quicker the reading is done the better. The observer will then enter the simple readings, but at the head of each column place the zero *correction* (with its proper sign) required for its thermometer, and leave a blank column for the hygrometric depression, or depression of the dew-point, in calculating which subsequently the zero must be *applied*.

The reduction of the observations to derive the *elastic force of vapour at the dew-point* is effected by the formulæ of Dr. Apjohn:—

$$F = f - \frac{d}{88} \cdot \frac{h}{30} \cdot \cdot \cdot \cdot (a); \; F = f - \frac{d}{96} \cdot \frac{h}{30} \cdot \cdot \cdot \cdot (b).$$

(*a*) To be used when the reading of the wet thermometer is above 32°, and (*b*) when below. In these formulæ *d* is the hygrometric depression, *h* the height of the barometer, *f* the elastic force of vapour for the temperature shown by the wet thermometer, to be taken from an appropriate table of the elastic force of aqueous vapour for every degree of temperature through a sufficient range, and F the elastic force of vapour at the dew-point, which (all other quantities being known) these formulæ enable us to calculate. If, with F so calculated the same table be entered under the column of force of vapour, the corresponding *temperature* is the dew-point, which, however, is not wanted to be known except for objects distinct from that of this process of hygrometry. In all these calculations Mr. Glaisher's 'Hygrometrical Tables,' which form a separate publication (second edition), will be found of great value, including as they do all the requisite data and corrections.

Among these tables, which were originally published in the 'Introductions to the Greenwich Meteorological Observations,' is one which shows the elastic force of vapour, in inches of mercury, for every tenth of a degree, from 0° to 90°, calculated from the experiments of Dalton, and those of the late Dr. Ure, noticed in the preceding part of this article. The history of this table we shall briefly state, as it involves the verification of the quantities now generally employed in the reduction of hygrometrical observations, as well as that by implication of Dr. Apjohn's formulæ already given. Before deciding upon the use of the table, many comparisons were made by Mr. Glaisher between the observed dew-point, and that deduced from the observed temperature of evaporation by means of the formulæ of Dr. Apjohn (originally published in the 'Proceedings of the Royal Irish Academy,' for 1840), using the values of the elastic force of vapour as given in the 'Report of the Committee of Physics including Meteorology' of the Royal Society of London, 1840; and also between it and that deduced from the values of that force and the formulæ given by Professor Kæmtz, in his work on Meteorology. It was found in this comparison that the errors of the inferred dew-points were considerable with both sets of tables. Similar comparisons were made, using the table in question, and the errors were found to be always small. Dr. Apjohn's formulæ, combined with it, gave results in close accordance with direct observations of the dew-point. It follows therefore that it represents with considerable accuracy, the relation between the tension and the temperature of steam.

We must not conclude, however, while on this branch of the subject, without directing the attention of the reader and hygrometrical observer, to the following remarks of Sir John F. W. Herschel: "The discussion respecting the formulæ and coefficients of reduction of observations of this nature can hardly be regarded as satisfactorily terminated; and it cannot be denied that great difficulty still subsists in determining, by any mere reading of instruments, the exact hygrometric state of the air. In the absence of direct observation of the Dew Point, the actual absorption and weighing of the water contained in a given volume of air seems to be the only method free from theoretical objection, and it might not be very difficult to contrive a portable apparatus for this purpose." 'Meteorology,' in 'Admiralty Manual of Scientific Enquiry,' 3rd edit., 1859, p. 134, note.

The 'Greenwich Magnetical and Meteorological Observations,' for the years subsequent to 1847, have appeared in an Appendix (also issued separately), to the annual volume of 'Astronomical Observations made at the Royal Observatory.' The hygrometrical deductions are stated for each month among the results of the ordinary meteorological observations, under the head of 'Humidity of the Air,' and consist of the temperature of the dew point, the elastic force of vapour, the weight of vapour in a cubic foot of air, the degree of humidity, and the weight of a cubic foot of air. From August 24, 1856, hourly observations have been made once in every week during twenty-four hours, the hygrometrical deductions from which, stated for each hour, include also that of the vapour required to saturate a cubic foot of air. Those deductions, together with the other meteorological elements, are further given in the form of monthly means. It is explained in the 'Introduction to the Observations for 1857' (the latest which have been published) that, the dew-point having been inferred exclusively (as noted in the preceding article) from simultaneous observations of the dry-bulb and the wet-bulb thermometers; in order to find the difference between the reading of the former and the dew-point, the difference between the dry-bulb and the wet-bulb readings has been multiplied by a factor taken from the following table, which has been deduced by Mr. Glaisher from the comparison of all the simultaneous readings of the dry-bulb, wet-bulb, and dew-point thermometers from the year 1840 to the end of the year 1854. The dew-point having been thus found for each individual observation, the mean has been taken for each day (as defined from midnight to midnight), and this mean is corrected by application of the elements in Mr. Glaisher's paper 'On the corrections to be applied to the Monthly Means of Meteorological Observations taken at any hour, to convert them into Mean Monthly Values;' 'Phil. Trans.' 1848, part i.

TABLE OF FACTORS BY WHICH THE DIFFERENCE OF READINGS OF THE DRY-BULB AND WET-BULB THERMOMETERS IS TO BE MULTIPLIED, IN ORDER TO PRODUCE THE DIFFERENCE BETWEEN THE READINGS OF THE DRY-BULB AND DEW-POINT THERMOMETERS.

Reading of Dry-Bulb Thermometer.	Factor.	Reading of Dry-Bulb Thermometer.	Factor.	Reading of Dry-Bulb Thermometer.	Factor.
20°	8·1	44°	2·2	68°	1·8
21	7·9	45	2·2	69	1·8
22	7·6	46	2·1	70	1·8
23	7·3	47	2·1	71	1·8
24	6·9	48	2·1	72	1·8
25	6·5	49	2·1	73	1·8
26	6·1	50	2·1	74	1·7
27	5·6	51	2·0	75	1·7
28	5·1	52	2·0	76	1·7
29	4·6	53	2·0	77	1·7
30	4·2	54	2·0	78	1·7
31	3·7	55	2·0	79	1·7
32	3·3	56	2·0	80	1·7
33	3·0	57	1·9	81	1·7
34	2·8	58	1·9	82	1·7
35	2·6	59	1·9	83	1·7
36	2·5	60	1·9	84	1·7
37	2·4	61	1·9	85	1·7
38	2·4	62	1·9	86	1·7
39	2·3	63	1·9	87	1·6
40	2·3	64	1·9	88	1·6
41	2·3	65	1·8	89	1·6
42	2·2	66	1·8	90	1·6
43	2·2	67	1·8		

(CLOUD; DEW-POINT; DEW; EVAPORATION; HAIL; HOAR-FROST; METEOROLOGY; RAIN; SNOW; VAPOUR.)

HYMEN, or HYMENÆUS, the god of marriage, was the son of Apollo and a muse. In very early legends he was described as a mortal of extreme beauty, who delivered from captivity some Attic virgins who had been carried to Eleusis by Pelasgian pirates. For this service he was rewarded with a maiden of whom he was deeply enamoured; and on account of his conduct, and the happiness of his marriage, he was invoked in bridal songs, thence called hymeneal songs. But several other legends are related, which account for his apotheosis in a somewhat different manner. In ancient art he is represented as a tall and elegant, but somewhat effeminate youth—a larger and more serious Eros. He usually carries in his hand the bridal torch, and sometimes wears on his head, or around his neck, a wreath of flowers.

HYMN (ὕμνος), a song of praise and adoration, in honour of a Deity, and by the Hebrews, as well as the Greeks, accompanied on some musical instrument. The *Te Deum* and *Benedictus* are, in our liturgy, both called hymns: the former is supposed to have been written by St. Ambrose; though St. Hilary, bishop of Poitiers, is said to have been the first who composed hymns for the church. To Prudentius is ascribed most of those which appear in the Roman breviary. The hymn should be a song of joy, not of lamentation, as is too often the case in the present day. Such was the opinion of St. Isidore, who gave to the song of complaint and sorrow the name of *threna*, from threnos (θρῆνος), "lamentation."

The term is now applied to any short religious poem sung in places of public worship, not being a version of a psalm, or taken directly from any of the canonical books of Scripture.

HYOCHOLALIC ACID ($C_{50}H_{40}O_{8}$). A peculiar crystalline acid, produced along with sugar of gelatin by the action of potash upon hyocholic acid.

HYOCHOLIC ACID ($C_{54}H_{43}NO_{10}$). This acid, in combination with soda, constitutes the chief portion of the bile of the pig. It is a white resinous body, fusible in hot water, and then presenting a silky appearance. It is very slightly soluble in water, by which it is distinguished from cholic acid. It gives insoluble precipitates with lime and baryta.

HYOCHOLOIDIC ACID. [HYODYSLYSIN.]

HYODYSLYSIN ($C_{50}H_{38}O_{6}$). An homologue of dyslysin, produced by the action of boiling hydrochloric acid upon hyocholic acid. It is insoluble in water, ammonia, and potash, tolerably soluble in ether, and but slightly soluble in alcohol. Its formation is preceded by that of a peculiar resinous acid, termed *hyocholöidic acid*.

HYOSCYAMINE, *Hyoscyama*, the active and alkaline principle of the *Hyoscyamus niger* and other varieties of henbane, from which it is obtained by a very complex and tedious process.

The properties of hyoscyamine are:—It crystallises in stellated groups, which have a silky lustre; and it is often obtained in the state of a colourless, viscid, adhesive mass. When perfectly dry it is inodorous; but when moist, especially if impure, it has a disagreeable stupefying smell, resembling that of tobacco. When anhydrous, hyoscyamine has not an alkaline reaction; but when mixed with water it has, on the contrary, very permanently alkaline properties. It is not volatile at common temperatures, and undergoes no change by exposure to the air. It melts at a low temperature, flowing like oil, and is volatilised at a high temperature; a large portion of it is then decomposed, becoming carbonised and yielding ammoniacal vapour. It is also partly volatilised by the vapour of boiling water, and communicates to the distilled water the properties of a narcotic poison. It is readily soluble in water, and iodine added to the solution gives a kermes-coloured precipitate; tincture of galls gives a white precipitate; chloride of gold precipitates whitish flocculi; solution of chloride of platinum gives no precipitate whatever. It dissolves also in alcohol and in ether.

Hyoscyamine burns with a sooty flame; concentrated nitric acid dissolves it without acquiring colour, and sulphuric acid renders it brown.

Hyoscyamine exists in combination with an acid; it neutralises acids perfectly, and its power of saturation is great. The salts which it forms by direct combination with dilute acid mostly crystallise, are inodorous, but have an acrid nauseous taste, are unalterable in the air, and are extremely poisonous.

Hyoscyamine is a narcotic poison, like narcotine, and proves fatal as quickly as conine.

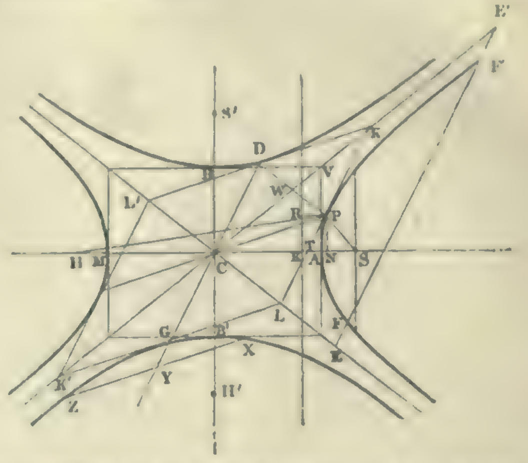
HYOSCYAMUS NIGER. The medical uses of *Hyoscyamus niger*, or henbane, have been detailed at the end of the article HYOSCYAMUS, in NAT. HIST. DIV.

HYPÆTHRAL. [TEMPLE.]

HYPE'RBOLA. In connection with this article see CONIC SECTIONS; ELLIPSE; PARABOLA.

The hyperbola is one of the curves known by the name of conic sections. It is in the application of mathematics the least useful of the three; indeed, so very rarely does the necessity of using it occur, that it may be a question whether the study of it should form a part of a course of practical mathematics. But there are in pure analysis so many analogies which are illustrated by distinctions existing between the properties of the ellipse and hyperbola, that the student who aspires to more than elementary knowledge cannot dispense with the comparison of the two curves.

The two branches passing through A and M form a complete hyperbola, derived from the cone, or from the general equation of the second degree. [CONIC SECTIONS.] There is a pair of straight lines passing through the CENTRE C, namely, L′C L and K′C K, which are ASYMPTOTES to the curve. There are two foci (as in the ellipse) S and H, the position of which may be thus found when the principal axis A M and the asymptotes are given: from A draw A V perpendicular to the axis; then C S and C H are both equal to C V.



The difference of the focal distances H P and S P is always equal to the axis major A M: in the branch passing through A, H P is greater than S P, and *vice versâ*. The tangent P T always bisects the angle S P H; and P N, the ordinate perpendicular to the axis, being drawn, C A is always a mean proportional between C T and C N. There is also a *directrix*, as in the ellipse, found by taking on the line C S, C E, a third proportional to C S and C A, and drawing through E a perpendicular to the axis; and, as in the ellipse, S P always bears the same proportion to P R, namely, that of C S to C A. And C S divided by C A is called the *excentricity*, the distinction between the ellipse and hyperbola being that in the former the excentricity is less than unity, and in the latter greater. The double ordinate drawn through S or H is called the *latus rectum* of the hyperbola, and its half the semi-latus rectum. Thus far the resemblance between the ELLIPSE and hyperbola is very visible: at the same time it is obvious that there is nothing in the latter which answers to the minor axis of the ellipse, or to conjugate semidiameters. But if another hyperbola be described in the manner immediately to be pointed out, a figure will be obtained which will enable us to point out properties answering in all respects to those of the ellipse. Complete the rectangle C A V B, and describe another hyperbola of which C B is the semi-axis, and the same lines as before the asymptotes. This hyperbola is said to be *conjugate* to the former one; and its foci S′ and H′ are at the same distance from the common centre as S and H.

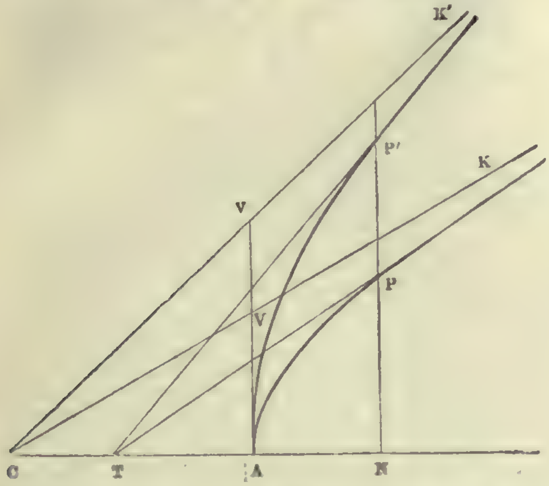
In the ellipse, C A was called the *major* semi-axis, as being greater than C B, the *minor* semi-axis. Let the words major and minor refer to the importance of the several axes, and not to their magnitude. Then C A is called the major semi-axis (or the semi-major axis) of the hyperbola passing through A and M, and C B its semi-minor axis. Conversely, C B is the semi-major axis of the hyperbola passing through B and B′, and C A is its semi-minor axis. Generally, the major axis of an hyperbola is that which cuts it, and the minor axis that which cuts the conjugate hyperbola.

As in the ellipse, the square on the ordinate P N is to the rectangle of M N and N A (which is the excess of the square of C N over that on C A) in the proportion of the square on C B to the square on C A. If C D be drawn parallel to the tangent P T, D is said to be conjugate to P, and the semi-diameter C D conjugate to the semi-diameter C P. . If the parallelogram P C D K be completed, the point K will always fall on the asymptote, and the other diagonal D P will be parallel to the other asymptote. And C P, any semidiameter falling in the acute angle of the asymptotes, always exceeds its semiconjugate C D; and the excess of the square on C P over that on C D is equal to the excess of the square on C A over that on C B. The area of the parallelogram C D K P always remains of one magnitude, namely, equal to C A V B. The rectangle of C W and W P always remains the same, namely, equal to the square on half the line joining A and B. Any part of a tangent K L, intercepted between the two asymptotes, is bisected by P, the point of contact; and if E E′ be drawn parallel to K L, the interceptions E F and E′ F′ are equal, and the rectangle of E F and F E′ is always equal to the square on P K or P L. And the rectangle of the focal distances H P and S P is always equal to the square of the semiconjugate diameter C P.

Any ordinate X Z drawn parallel to a tangent G L is bisected by the diameter C G drawn through the point of contact. And the square on Y X is to the rectangle of D Y and Y G (or the difference of the squares on C Y and C G) in the proportion of the square on C P to the square on C D.

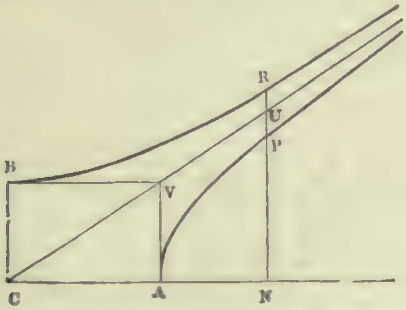
A perpendicular let fall from a focus S upon a tangent P T meets the tangent in a point of the circle whose centre is C and radius C A.

If any number of hyperbolas be drawn having the same centre C and the same major axis C A, and ordinates N P, N P′, &c., be drawn to the same abscissa C N, the tangents at P, P′, &c., will all meet the axis C A in the same point T: and any two such ordinates P N, P′ N, will



always be to one another in the proportion of the minor axes of the hyperbolas to which they belong.

If it were not necessary to consider the hyperbola in connexion with the ellipse, perhaps the following way of describing it would be the most simple.



Let C A be the semi-axis major, and C U one of the asymptotes: and while the line N U moves parallel to A V, let P move upon that line in such a way that the square on N P shall always be less than the square on N U by the square on A V. Then P will trace out one branch of the hyperbola. But if at the same time the square on R N *exceed* the square on N U by the square on A V, the point R will trace out a branch of the conjugate hyperbola.

For a remarkable property of the area of an hyperbola see LOGARITHMS.

Among ellipses there is one sort which is conspicuous, namely, the ellipse in which the major and minor axes are equal, or the *circle*. The corresponding hyperbola, namely, that in which the major and minor axes are equal, is called the *equilateral* hyperbola; and though not so remarkable a curve as the circle, yet presents some peculiar simplification of properties. Its asymptotes are at right angles to one another, and the hyperbola and its conjugate are similar and equal. Any semidiameter C P is equal to its semiconjugate C D, and P D is at right angles to C W. Its excentricity is $\sqrt{2}$ or 1·4142 ...., and the square on C N always exceeds the square on N P by the square on C A.

In the preceding article it will be observed that we have called the two branches passing through A and M *one* hyperbola. They are frequently called two *opposite* hyperbolas; but they form in fact only one curve, defined by one equation.

HYPERBOLE (*ὑπερβολή*, from *ὑπέρ* above, *βάλλειν* to throw) means literally an over-casting; in its common sense, a going beyond the truth in describing an object, not by the introduction of qualities which do not belong to it, but by the exaggeration of those which do. For example, it may be hyperbolical to say that the complexion of a fair woman is whiter than snow; but to say so of a brown woman is either irony or simple falsehood. Poets in all nations have affected this mode of speech; but it is peculiarly characteristic of the Oriental nations, both in prose and verse.

HYPERBOLOID. [SURFACES OF SECOND DEGREE.]

HYPERION, a Titan, the son of Uranus and Ge, and father of Selene, Eos, and Helios, who is often called Hyperion. [HELIOS.]

HYPERSPIROILIC ACID. [SALICYLIC ACID.]

HYPERTROPHY (from *ὑπέρ*, above, and *τροφή*, nutrition), a term in medicine signifying the enlargement of a part of the body from excessive nutrition. The hypertrophied organ contains no new solid or fluid substance, but one or more of its proper component tissues are in greater quantity than in the healthy state. The opposite condition of a part—namely, diminished bulk from defective nutrition—is termed atrophy. [ATROPHY.]

When hypertrophy attains such a degree as to interfere with the action of the organ in which it is seated, it constitutes an important and highly dangerous disease; such is frequently hypertrophy of the heart. [HEART, DISEASES OF.]

The immediate cause of the hypertrophied state is, as we have said, increased nutritive action in the organ or tissue; and since all parts of the body are formed and nourished from the blood circulating in them, it is natural to suppose that the production of hypertrophy would be accompanied by increase of the quantity of that nutritive fluid in the part. It is necessary, however, not merely that the blood should be collected in it in larger quantity, but also that it should circulate rapidly through the minute vessels, so as to bring constantly fresh portions of new nutritive matter into contact with the smallest component particles of the structure. This is illustrated by reference to the known exciting causes of hypertrophy which give rise primarily to this increased quantity and accelerated circulation of blood in the small blood-vessels. There are, it is true, instances of hypertrophy of which we cannot perceive any exciting cause: thus, in some persons the adipose tissue, or fat, in others the bones, are more than ordinarily developed, without our being able to assign any other reason for it than that there was a predisposition in the constitution of the individual to such increased nutrition. But generally we can refer the hypertrophy either to excessive exercise of the part, or to the long-continued action of a stimulus upon it. When any part is in a state of activity, a greater flow of blood takes place towards it than when it is at rest; and it is well known that a stimulus such as friction applied to a part of the body causes it to become of a brighter red colour from its vessels being more injected with blood. If such a state be long kept up, over-nourishment is the result. A popular example of hypertrophy from increased exercise is afforded by the muscles of the arms of the blacksmith, or those of the legs of the opera-dancer. The heart also frequently becomes hypertrophied from this cause; for instance, in cases where an increased action of its muscular walls is rendered necessary by an obstacle to the passage of the blood, which it propels into the body. Hypertrophy from the second cause, the long-continued operation of a stimulus, is seen in the thickened state of parts of the skin which have been subjected to friction. But hypertrophy from this cause is seldom simple; it is generally combined with the deposition of new matter of a different nature from the original tissue, the stimulus having excited inflammatory action as well as increased nutrition.

The treatment of hypertrophy consists in the removal of the exciting cause, if this can be effected: the part should be kept at rest as much as possible, all irritation prevented, and the supply of blood diminished. These means can, however, in very few cases be put into practice to such an extent as to be beneficial, except in arresting the progress of the affection.

(Andral, *Pathological Anatomy*; Carswell, *Illustrations of the Elementary Forms of Disease.*)

HYPERURIC ACID ($C_{10}N_4H_5O_9$), *Peruric Acid*, discovered by Unger, and formed by acting on guanin with hydrochloric acid and chlorate of potash. It differs in composition from uric acid by 1 equivalent of water and 2 of oxygen: hence its name. It is colourless, and crystallises in short rhombic prisms, and when heated is resolved into hydrated cyanic acid, water, and carbon.

HYPO and HYPER. [CHEMICAL NOMENCLATURE; *Nomenclature of Acids.*]

HYPOCAUSTUM. [BATH.]

HYPOCHLORIC ACID. [CHLORINE.]

HYPOCHLOROUS ACID. [CHLORINE.]

HYPOCHONDRIASIS, is a state of extreme sensibility of the nervous system, which leads patients to believe themselves worse than they really are, to detail their sufferings with exaggeration, to individualise all the painful sensations which they experience, and to consider them the symptoms of as many different diseases. Allied to this extreme sensibility there is a mental exaltation, which causes the patients to pay the most minute attention to what passes within themselves. The hypochondriac recounts, without a single omission, all the details of his animal and organic life; he relates the manner in which his digestion is effected; he numbers the minutes of his sleep; he describes his sensations, his passions, the succession of his ideas; and dilates on every thing that concerns himself with a copiousness that nothing can arrest. The story which he tells you to-day he will relate again to-morrow, and at all times whenever he can find you willing to listen to his tale of sufferings.

The case of a gentleman is related who was so engaged in attention to himself as to occupy the intervals of the visits of his physician in writing a journal of his sensations. This journal was, at every visit of the physician, produced for his perusal. During a period of several years this gentleman was, without any adequate reason, almost daily in dread of immediate death, and was continually upbraiding his medical attendant and charging him with the greatest cruelty in coming so seldom to see a man in such imminent danger.

As we do not in general see in hypochondriacs any loss of flesh or any appearances of disease corresponding to the frightful picture which they draw of their sufferings, we take them for visionaries; and such, in most instances, they really are. M. Leuret relates the case of a hypochondriac, who one day, among other symptoms of which he complained at great length, said that he could extend his leg slowly only and with difficulty, and to show to what an extremity he was reduced he lifted the limb with an appearance of great effort. "Well! what can you wish more?" inquired M. Leuret. "Zounds;" cried he abruptly, "to do this;" and at the same time he extended his leg with great freedom and force. M. Leuret could not restrain his laughter; and his patient, on perceiving the mistake that he had made, laughed also most heartily.

The sufferings of hypochondriacs have been called imaginary, and, if it is meant that they are a product of the imagination, the appellation is just; but the appellation of "imaginary" is false if it is pretended that they are not really felt. Of all patients, those whose diseases are imaginary probably suffer the most. In many cases however these persons are affected with a real disease, and the term hypochondriasis is applicable to them only in consequence of their having their attention constantly fixed on their complaint, and of their experiencing a degree of fear and sadness which their condition does not warrant.

Hypochondriasis is frequently witnessed in young men of studious habits, and is the result of intellectual application too much prolonged. There is a class of students who, from the nature of their studies, are frequently affected with it—we allude to students in medicine. The descriptions which they read and hear of diseases, and the continual observation of the sick, affect their imaginations. They learn that incurable diseases often arise in the most insidious manner. They apply to themselves the lessons they have just learned; but as these lessons are very incomplete, their application is false, and they discover in themselves a number of diseases of which there is no real existence. There are few physicians who, in recalling to their minds the period of their first studies, and the sick whom they first visited, do not at the same time remember the inquietude which they experienced respecting their own health. Persons in the habit of reading medical books run the same risk as medical students, and are similarly affected.

Another very fertile source of hypochondriasis is luxury, and the want of occupation and exercise. The hypochondriasis produced by this cause is the most obstinate of all, and is at once the despair of the patient and the torment of the physician. Happy are those whom the possession of a competence, earned by the labour of each day, preserves from such a malady. Poverty itself, with all its privations, is attended with less misery than the riches of the hypochondriac.

Hypochondriasis occasionally results from other causes, such as misfortunes, the excesses to which young men are addicted, and the prolonged and injudicious use of medicines.

The treatment of hypochondriasis must of course vary in some degree with its cause. We must endeavour to allay the groundless fears of hypochondriacs, and by a change in their mode of life, and by diverting their attention, to break the habit which they have formed of continually brooding over themselves. The first point, and which is quite essential, is that the patient should have an entire confidence in his physician. Confidence begets tranquillity, and banishes all those symptoms that originate in fear.

If hypochondriasis result from severe study, a relaxation from labour, and the distractions of society, with a country life, will prove the most efficacious remedies.

If it is occasioned by idleness and luxury, a solid and permanent cure can rarely be obtained except by a life of occupation, a moderate regimen, and bodily exercise long sustained. The field sports of this country are admirably adapted to the fulfilment of these conditions. Instances have been recorded of patients having been freed from the hypochondriasis to which they have been long a prey by the loss of their fortunes, or by some calamity which roused them from their state of apathy and rendered exertion imperative.

In all cases a remedy must be sought for in the banishment of their groundless fears, in a change in their mode of life, and in scenes that withdraw them from the continual contemplation of themselves.

HYPOGEIC ACID ($C_{32}H_{30}O_4$). An acid homologous with oleic acid, obtained along with *arachidic acid* by saponifying the oil expressed from the seeds of the *Arachis hypogæa*. It crystallises in needles, soluble in alcohol and ether. [Arachidic Acid.]

HYPONITRIC ACID. [Nitrogen.]

HYPONITROMECONIC ACID. [Opium, Alkaloids of; Narcotine.]

HYPONITROUS ACID. [Nitrogen.]

HYPOPHOSPHOROUS ACID. [Phosphorus.]

HYPOPION (from *ὑπώπιον*), a collection of purulent matter in the anterior chamber of the eye. Mr. Lawrence ('Treatise on Diseases of the Eyes') shows that this should not be regarded as a separate disease, but as the result of inflammation of some part adjacent to the anterior chamber. The purulent matter is in some cases secreted by the membrane of the aqueous humour; in others it proceeds from the bursting of an abscess of the cornea or of the iris. The pus poured into the anterior chamber being heavier than the fluid which naturally fills that cavity, falls to the bottom, and produces an opaque spot which is visible through the cornea, and has its upper edge horizontal, and its lower edge, which is bounded by the margin of the cornea, crescentic. The affection is always accompanied by inflammation of part or of the whole of the tissues of the eye, and, like all other such cases, requires active antiphlogistic treatment.

HYPOSULPHAMYLIC ACID ($C_{10}H_{12}S_2O_6$). An acid similar to the hyposulphethylic acid, but containing the radical amyl in the place of ethyl. [Hyposulphethylic Acid.]

HYPOSULPHETHYLIC ACID. Synonymous with *Ethylsulphurous acid.* [Ethyl.]

HYPOSULPHINDIGOTIC ACID. [Indigo.]

HYPOSULPHONAPHTHALIC ACID. [Naphthalic Group.]

HYPOSULPHONAPHTINIC ACID. [Naphthalic Group.]

HYPOSULPHURIC ACID. [Sulphur.]

HYPOSULPHUROUS ACID. [Sulphur.]

HYPOTHEC (from the Greek *ὑποθήκη*, a security, literally the subjection of a thing to the authority of another person) is a term derived from the civil law, still in use in the law of Scotland, and in that of France with the lingual variation *hypothèque;* while, though in the law of England it is not a received technical expression, it is occasionally used for describing any species of security holding the character which the word was employed by the civilians to represent. Hypotheca in its proper acceptation signified a right of security over something which was not placed in the creditor's possession, in contradistinction to pignus, which applied to what is now termed a pledge. See the distinction, pretty clearly drawn, in the Institutes of Justinian, 4. 6, 7 and in the Digest, 13. 7; 9. 2: "Propriè pignus dicimus, quod ad creditorem transit; hypothecam, cum non transit nec possessio ad creditorem." But the distinction is often lost sight of, even in the original authorities of the civil law; for the Roman lawyer Marcianus says that the difference between the two expressions is merely nominal (D. 20. 1, 5); and see Brissonius de Verborum Significatione, *voce* Hypotheca. Hypothecs were distinguished into those created by contract, and the tacit or prætorian, admitted in certain circumstances without stipulation. The law on the subject will be found in the Pandects, lib. xiii. tit. vii. de Pignoratitia Actione, &c. (above referred to); in lib. xx. de Pignoribus et Hypothecis; and in the Code, lib. viii. tit. xiv. The reader will also find a short but clear summary of the Roman rules on this subject in Warnkœnig's 'Institutiones Juris Romani,' lib. ii. cap. v. §§ 450–478.

The several securities over real property in various parts of the empire, which can be completed without the absolute transfer of the property to the creditor, are so many illustrations of consensual hypothecs in that description of property. Consensual hypothecs in moveables are nearly unknown in the British empire, as the law, studying the interests of commerce, has discouraged any latent right in favour of an individual over merchandise and other moveable goods while they are left apparently at the disposal of the original owner, and are liable to be viewed by all who transact with him as his property. Bottomry and Respondentia are perhaps the only instances in which it is countenanced. But there are still some tacit hypothecs created by the operation of law, affording a preference to particular creditors over the property of a person who cannot or will not pay all his debts. Used in this sense, hypothec is properly the counterpart of lien, the former being a tacit security over property which is in the debtor's hands, the latter over property in the creditor's hands. Those provisions in the excise laws which give the revenue a preference over exciseable commodities, and the instruments used in their manufacture, are strictly the creation of tacit hypothecs. The provisions in the bankrupt acts for paying servants' wages and other debts out of the readiest funds of the bankrupt are the establishment of a general hypothec over the estate.

In Scotland, the landlord's privilege to seize the tenant's goods for arrears of rent is called a hypothec while it is unexercised; that is to say, before execution against them is commenced the landlord is said to have a hypothec over the goods; and this right, it is said, covers not only the ordinary rent, but also the additional rent stipulated in the event of deviation from the terms of the cultivation clauses (but this doctrine has been strongly attacked). On an agricultural farm the crop stands hypothecated for the rent of the year of which it is the produce. The landlord's right exists so long as the crop is on the farm, and it extends to the revendication of it even from a *bonâ fide* purchaser within three months after the rent has fallen due, unless he have been a purchaser by bulk in open market. The hypothec for other effects—as the cattle on a farm, the tenant's furniture in a house—subsists over the whole for each term's rent, and gives a preference for three months after the rent is due. The landlord's hypothec is not affected by the bankrupt statutes. In Mr. Hunter's able treatise on 'Landlord and Tenant,' the origin and effect of this branch of the law of Scotland is discussed with great clearness and precision, and for the purposes of practical reference the reader is referred to that work; the following points, however, extracted from it, are deserving notice: 1st, that the earliest, and indeed the original, remedy given the landlord for the recovery of his rent, was by brieve of distress; and that, 2ndly, it was not till the beginning of the 17th century (1623) that the term hypothec appeared in the decisions, from and after which period distress ceased and hypothecation prevailed; 3rdly, that there is so obvious a distinction between these two remedies, arising from the more extensive operation of hypothecation in following and realising the effects, as to lead to the conclusion that the rules and phraseology of this system are drawn directly from the Roman jurisprudence; 4thly, that the Scotch right of hypothec is not to be deemed a right of property, but a right arising from a tacit contract, inseparable from the contract of lease; 5thly, that this right is purely legal, and cannot be created by convention,—the only conventional hypothecs known to the law of Scotland being bottomry and respondentia; and, lastly, that the rules relative to hypothec have arisen from the common law without the intervention of statute. Another right of a different description is called a hypothec in Scotland—namely, the right of a law agent to take his client's decree for expenses, or judgment for costs, in his own name, in order that he may recover payment of his account as taxed by the auditor of court. This right cannot be defeated by a collusive settlement. In Scotland, a law agent, whether employed to conduct a litigation or in other professional business, such as conveyancing, is entitled to retain his employer's title-deeds and papers until his just account is paid. This right has also been called a hypothec; but it is clearly a lien. For further information on this part of the Scotch law of hypothec, the reader is referred to Bell's 'Commentaries,' vol. i.

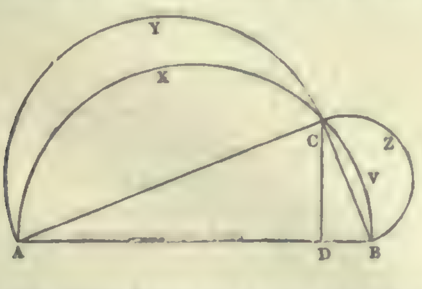
In France there is a distinction between privilèges and hypothèques. All tacit hypothecs, according to the division above kept in view, are included under the former, which are subdivided into a general preference over all the moveables or personal property in the debtor's possession, and limited preferences over particular articles of property for particular obligations. This last named, in so far as it affects moveable property, is the class of rights which has been spoken of above as tacit hypothec, and it includes the landlord's security for his rent. There is also a classification of privilèges sur les immeubles, consisting of tacit preferences over what is in England called real property, and of privileges which extend to both moveable and immoveable property. The term hypothèque is applied to conventional securities over immoveable or landed property, and is the object of much useful legislation; such securities being, from the efforts to give virtual effect to the law for partition of successions, without reducing them below the proper extent for agricultural operations, more common in France than perhaps in any other part of the world. See on the matter of the immediately preceding remarks, 'Code Civil,' lib. iii., tit. 18; and Troplong, Droit Civil expliqué, 'Privilèges et Hypothèques.'

HYPOTHECATION. [Mortgage.]

HYPOTHENUSE or HYPOTENUSE (ὑπο-τεινουσα, subtending), is a term which has always been applied since the time of Euclid to the side of a *right-angled* triangle which subtends, or is opposite to, the right angle.

The property of the hypothenuse of a right-angled triangle being one of the most important elementary propositions in the whole of mathematics, it will be worth while to devote some space to its consideration. We shall proceed to give some demonstrations, derived from different principles.

The property in question, in a limited form, is this: that the *square* on the hypothenuse is equal to the sum of the *squares* on the sides. The introduction of the square, however, in preference to any other figure, arises from the fact of the property of the hypothenuse with respect to the square being demonstrated before that with respect to any other figure. The general proposition is this: if three similar figures (that is, figures of the same shape, differing only in size) be described upon the three sides of a right-angled triangle, the content of that which is described upon the hypothenuse will be equal to the sum of the contents of the figures described upon the sides. Thus, all semicircles being similar figures, let A X C B, A Y C, and C Z B, be the semicircles described on the hypothenuse and sides of the triangle A C B, right angled at C: then A Y C and C Z B are together equal to A X C B. Hence was obtained the first instance in which a curvilinear space was reduced to an equivalent rectilinear one. Take away the segments A X C and C V B from both sides of the preceding equation, and the remainders of the smaller semicircles, namely, the *lunules* Y X and Z V, are together equal to the remainder of the larger one, namely, the triangle A C B. This proposition is attributed to Hippocrates. [Geometry.]

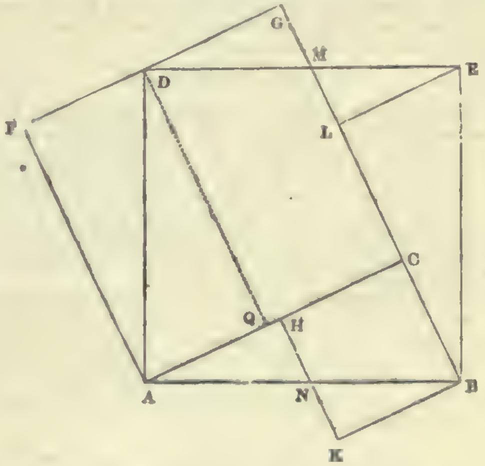


So soon, however, as the proposition is demonstrated with respect to squares, all the rest follows easily, after the doctrine of proportion has been established. It is the property of similar figures described on two lines to be in the same proportion as the squares on those lines; if then the squares on two lines be together equal to that on a third, then any two similar figures described on the first two lines are together equal to the corresponding figure described on the third.

We shall now sketch four different demonstrations of this fundamental proposition, desiring it to be remembered that we suppose the reader to have already become acquainted with it in an elementary course of geometry.

1. Let C D (in the preceding figure) be drawn perpendicular to A B. Suppose that (after the manner of some writers on geometry) the theory of proportion and of similar triangles is established before anything is proved relatively to the areas of figures. Then it is easily shown that A C D and C D B are triangles similar to one another, and to the whole A C B. Now in such a system of geometry, it can easily be shown, without the aid of our theorem, that any two similar figures, described on two straight lines, are to one another in the proportion of the squares on those lines. Consequently, A C B, A D C, B D C, being similar triangles described on A B, A C, B C, are to one another as the squares on A B, A C, B C. But the first triangle is evidently equal to the sum of the other two: consequently, the square on A B is equal to the sum of the squares on A C and C B. This demonstration may be objectionable in a geometrical point of view, but it contains one of the most useful modes of illustrating the proposition to a person unacquainted with geometry. Let such a one be made to remark the very visible fact, that two similar figures described on two straight lines are always of the same relative magnitude, each to the square described on the same line: he will then, seeing that the right-angled triangle is made up of two right-angled triangles similar to itself, each having one of the sides for its hypothenuse, be able to see that the square on the hypothenuse is equal to the sum of the squares on the sides.

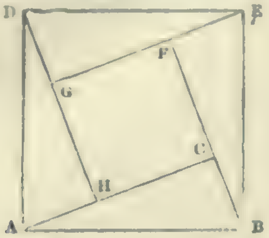
2. The next method shall be ocular demonstration, made by cutting the square on the hypothenuse into the squares on the sides. Let A C B be the triangle, right-angled at C; and on A B describe the square A D E B, and on A C and C B the squares A F G C and C H K B. From E draw E L perpendicular to B M, and from D draw D Q perpendicular to A C. It is easily proved that the triangles A C B, B L E, D Q A, are equal in all respects; whence (1) the line F G must pass through D, since D Q = A C; (2) E L = B C = B K. Hence, by the parallels, the triangles N K B and M E L are altogether equal, so that E M = B N, whence M D = N A, and, by the parallels, D G M and A H N are altogether equal. And A F D is in all respects equal to B L E. Out of the square A D E B take B L E, and remove it to A F D; remove M L E to N K B, and A H N to D G M. Then the square A D E B will be formed into the two squares A F G C and H C B K.



In a paper by Professor Kelland, 'On Superposition' ('Edinb. Trans.' vol. xxi. p. 2) are *twelve* different ways of dissecting a square into two squares, one of which shall be three times the other. This paper suggested to Mr. Airy, the Astronomer Royal, the following very simple mode of making *any* two squares into one; from which a demonstration of i. 47, may be derived of a more elementary character than that given by Euclid himself. Place the squares A G, K C, side by side, as in the preceding diagram; and make G L equal to B C, as before. Join F, L and L, K, then F L, L K are equal and perpendicular to each other. Turn the triangles F G L, L B K, round the points F, K until F G coincides with F A, and K B with K H. The two squares will thus be turned into the square on F L or L K. The same thing may be done by translation of the triangles, without rotation. It is rather singular that, many as have been the eyes which have rested on the preceding diagram, no one should ever have made it yield the dissection just given.

Each mode of demonstrating a geometrical proposition usually belongs to its own particular generalisation of that proposition. The one last before us suggests the following generalisation:—If any two triangles have a pair of supplemental angles, and if the sides opposite to those angles be called hypothenuses, and if P, Q, be the remaining sides of one triangle, and P′, Q′, of the other, then two parallelograms having the supplemental angles for their angles, and P and P′ for the sides of one, and Q and Q′ for the sides of the other, are together equal to the parallelogram under the hypothenuses inclined at one angle equal to the sum of those opposite to P and Q′, or to P′ and Q.

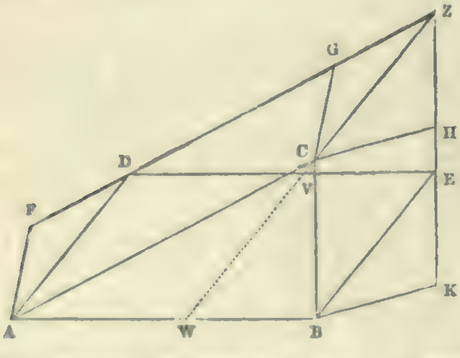
3. The next demonstration is derived from the Hindu treatises on algebra: not that it is actually found there, for the Hindu works demonstrate nothing; but attached to the statement of the proposition, in the margin of some copies, is the following diagram, which is no doubt that belonging to the demonstration, which is as follows:—Let ACB be the triangle, and describe the square ABDE on the hypothenuse. Draw DH perpendicular to AC, and EG perpendicular to DH, and produce BC to meet EG in F. Then the square is made up of the four equal triangles ACB, BFE, EGD, DHA, and of the smaller square GFCH, which is the square on HC, the difference of AC and CB. But the four triangles make up twice the rectangle of AC and CB, and twice the rectangle on two lines, together with the square on their difference, is the sum of their squares: whence the square on AB is the sum of the squares on AC and CB. Judging by the general character of Hindu mathematics, it must be supposed that their demonstration was arithmetical, supposing the sides of the triangle to be represented by numbers, and using the equation



$$(a-b)^2 + 2\,ab = a^2 + b^2.$$

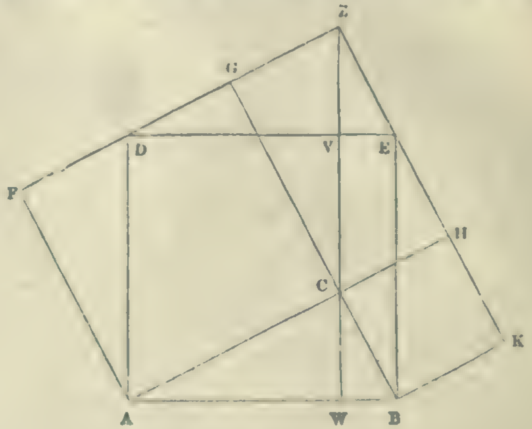
The following is the method of obtaining right-angled triangles, of which the sides shall be whole numbers. Take any two whole numbers whatsoever, x and y, of which x is the greater; then if x^2-y^2 and $2\,xy$ be the two sides of a right-angled triangle, the hypothenuse is x^2+y^2. For instance, let $x=11$, $y=7$; then $x^2-y^2=72$, $2\,xy=154$, and $x^2+y^2=170$: whence 72 and 154 being sides of a right-angled triangle, its hypothenuse is 170. It is a remarkable property of any three numbers which represent the sides of a right-angled triangle, that one of them must be divisible by 5.

4. The last demonstration which we shall give is one which shows the property in question to be but one simple and prominent case of a property of great beauty and generality, common to all triangles. This property was first noted by Pappus, and it shows that any parallelograms whatsoever being described upon the two sides of a triangle, a third parallelogram, equal to their sum, can immediately be drawn upon the third side.



Let ABC be a triangle, on two sides of which, AC and CB, let any parallelograms AFGC and BCHK be described. Produce FG and KH to meet in Z, and join ZC, and produce it to W. Through A and B draw AD and BE parallel to ZW, whence it follows that ADZC and CZEB are parallelograms, and, by equality of bases and altitudes, severally equal to AFGC and CHKB. And AD and EB are equal and parallel to ZC, and therefore to one another; whence ADEB is a parallelogram made up of the parallelograms ADVW and BWVE, which, by equality of bases and altitudes, are severally equal to ADZC and BCZE, that is, to AFGC and CHKB. Hence the parallelogram on the side AB is equal to the sum of those on the sides AC and CB.

Now let the triangle be right-angled at C, and let the parallelograms on AC and CB be squares, and repeat the preceding construction. Then GCHZ is a rectangle, and GZC is in all respects equal to ACB, whence ZC=AB, and thence AD and BE are equal to AB, and the parallelogram DEAB is equilateral. But the angle DAC is equal to ZCH, which is equal to CBA, the triangles CZH and BAC being altogether equal. But CBA and CAB are together equal to a right angle; whence DAC and CAB are the same, or DAB is a right angle. Consequently, ADEB is an equilateral parallelogram, right angled at A, or it is a square; and the parallelogram ADEB, that is, the squar on AB, is equal to the sum of the parallelograms AFGC and CHKB, that is, to the sum of the squares on AC and CB.



HYPOTHESIS (*ὑπό-θεσις*, *sub-positio*, supposition), literally, the act of placing one thing under another, that the latter may stand upon and be supported by the former; by extension, the assignment of cause or reason sufficient to make it a consequence that an event or phenomenon must happen. For instance, the sun would disappear if it were deprived of its power of giving light, and also if an opaque body came between us and it: either of these circumstances would cause what we term a total eclipse, and either is therefore sufficient, as an hypothesis, to explain a total eclipse.

In the article CAUSE (in natural philosophy) will be found the discussion of several considerations connected with the use of hypotheses; and in the article ATTRACTION an instance of the important distinction between an hypothesis asserted because it is true, and one assumed because it is sufficient to explain observed phenomena. We suppose these articles to be known to the reader.

The following mode of argument is known in logic by the name of a hypothetical syllogism:—If A exist, Z exists; but A does exist, therefore Z does exist. Or, establish the absolute truth of an hypothesis, and the phenomena which necessarily follow may be asserted even without experiment. But this we are seldom in a condition to do. The preceding process cannot be converted: if A exist, let Z necessarily follow; Z has appeared, are we then entitled to say that A exists? By no means; for when we prove that Z necessarily follows from A, we do not therefore show that Z follows from nothing but A. But if we can establish the following:—If A exist, Z follows; if B exist, Z follows; if C exist, Z follows; and Z cannot happen in any other way: then from the arrival of Z we are entitled to assume that one of the three, A, B, or C, must necessarily exist, perhaps two, and perhaps all three. At the same time, if the existence of the consequence can be denied, the hypothesis is overthrown. If A exist, Z follows; but Z does not happen; then it is perfectly certain that A does not exist. The following summary of the four cases may be more worthy of our readers' consideration than many of them will suspect:—

1. When A is B, Y is Z.
   But A is B. } Therefore Y is Z.
2. When A is B, Y is Z.
   But A is not B. } Nothing can be concluded: Y may be Z on some other grounds, or Y may not be Z precisely because A is not B, or for some other reason.
3. When A is B, Y is Z.
   But Y is not Z. } Therefore A is not B.
4. When A is B, Y is Z.
   But Y is Z. } Nothing can be concluded: A may be B, and either because Y is Z, or for some other reason; and A may not be B, and there may be some other reason why Y should be Z.

The establishment of an hypothesis in natural philosophy may be considered as a process of which the following are the heads:—

1. The phenomenon observed is Z, and it is shown to be a necessary consequence either of A, B, or C, which seem natural and probable: also of D, E, &c., which seem altogether out of the question.

2. All the necessary consequences which can be shown to follow A, B, or C, are deduced as far as that can be done; and if all their consequences really happen, then there is no choice between A, B, and C; but if Z′, a necessary consequence, say of C, should be found not to happen, then C cannot exist, and the choice can only lie between A and B.

3. Let A appear the more probable of the two, then A is assumed to be the cause of Z until something to the contrary appears. If A and B should be inconsistent with one another, then if one be assumed, it

must be to the exclusion of the other; but if both may be true, then the phenomenon E may possibly be partly due to one and partly to the other.

An hypothesis thus assumed is obviously no more than a probable truth; and the existence of sects embracing different hypotheses is thus rendered not only natural, but even desirable. The consequence of such division is, an ardour of investigation which would not otherwise be felt, in order to find out experiments or to make deductions decisive of the points in dispute. The rivalry between the emanatory and undulatory hypotheses on the nature of light has much increased our knowledge of that agent. But if at the same time it should seem that the idea which a reader entertains of physical science must be lowered by his learning to take such a view of a hypothetical foundation as that which has here been given, it should also be remembered that the exactness of natural philosophy does nothing but expose the uncertainty of human knowledge in general, at the same time that it reads a lesson to the cultivators of other branches of learning. The hypothesis of attraction, for instance, though established on much stronger grounds of probability than conclusions in connexion with which the word hypothesis is never mentioned, is remembered as being only an hypothesis.

At the same time the word hypothesis, like that of theory, has been frequently applied in a disparaging sense to speculations in which suppositions have been made for the purpose of drawing conclusions, and not, as in physics, with the view of supplying probable antecedents to conclusions which are already drawn from experiment. A notion is to be supported; it would be too obvious a fallacy to make the mere assertion of it an argument in its own favour, and thus some antecedent proposition, from which the one in question will follow, is assumed or attempted to be proved. To prove D, assume A, taking care that it shall be easy to show that from A follows B, from B follows C, and from C follows D. This is a use of hypothesis the direct converse of that which is made in physics, where D is supposed to be known and admitted, and it is asked which among all the A's from which it might follow is that from which it most probably does follow. [CAUSE.]

HYPOXANTHIN ($C_{10}H_4N_4O_2$). A peculiar substance met with in the fluid of the human spleen, and also in that of the ox. It has also been found in the fluid pressed from the muscles of the heart, and in small quantity in the blood of oxen. It presents the appearance of a white crystalline powder, which is almost insoluble in cold hydrochloric acid. One part of hypoxanthin requires 1090 parts of cold, or 180 parts of boiling, water for its solution. It is very slightly soluble in boiling alcohol. Its solution in water possesses a neutral reaction.

HYPSOMETRY. The process by which heights are measured by the indications of the barometer. [HEIGHTS, MEASUREMENT OF; BAROMETER.]

HYSTERIA (from *ὑστέρα*, the womb) is, in general language, understood to signify those paroxysms to which females are subject, and which are attended with convulsions, a sense of choking, and involuntary laughing or crying. But the term is used in medicine as a general expression to include a vast number of other symptoms known as "nervous disorders," all dependent on a peculiarly susceptible state of the nervous system.

We will first consider the different forms of hysteric affection.

The hysteric fit or paroxysm need scarcely be described, except for the purpose of pointing out how it may be distinguished from fits of other kinds; and this is a matter of no little importance, not only as regards the treatment required and the temporary alarm of the friends, but also with relation to the happiness and prospects of the sufferer. For it appears that in France, at least, young females labouring under mere hysteria have been separated from their families and society, and placed in confinement under the idea that they were the subjects of epilepsy, a disease which is thought to be hereditary, is but too often incurable, and leads to loss of intellect. The hysteric paroxysm generally commences with the sensation of a ball in some part of the abdomen or in the left side, which rises with a twisting vermicular feeling to the throat, where it induces a sense of suffocation. A temporary state of loss of sense and voluntary power succeeds, in which the patient either lies motionless, or is agitated with violent struggles of the limbs; the head is struck against the bed or floor, and the hair or the breasts are grasped and torn with the hands. Frequently the patient tries to bite herself or the bystanders. The involuntary expulsion of the contents of the bladder not uncommonly takes place during the fit. In the absence of convulsions there is often immoderate laughter, crying, or singing, and the paroxysm is frequently terminated suddenly by a burst of tears. More usually the patient lies quietly for some time after the convulsions cease, and when she recovers complains of headache. Frequently she proves that consciousness has not been entirely lost, by repeating what has been said by those around her. The attack of epilepsy differs from that of hysteria in not being preceded by any sensation of a ball rising to the throat; the epileptic patient falls suddenly to the ground, and is immediately violently convulsed; the eyes are distorted, and the tongue protruded and bitten. In hysteria the features are generally tranquil, and the face is flushed; whereas in epilepsy it is often of a ghastly paleness. The epileptic fit is in many cases ushered in by a short cry, but there is no laughing, crying, or singing during the paroxysm, or at its termination, as in hysteria. Lastly, the loss of consciousness is complete in epilepsy, generally not so in hysteria. These are the principal points of difference. It is well to remark in addition that hysteria is almost confined to women, and that the paroxysm is generally preceded by some strong mental emotion; while epilepsy is most frequent in men, and more usually attacks the patient during the night, or between the states of sleep and waking. Repeated attacks of epilepsy leave imprinted on the countenance a peculiar dull expression which is not seen in the hysterical.

"Nervous" females are very liable from the slightest causes to hurried respiration, sighing, sobbing, and palpitation; the irregular and hurried breathing may become occasionally so aggravated as to resemble asthma, from which it is to be distinguished by its occurring in young persons, and by its being accompanied by other hysterical symptoms, and a peculiarly irritable susceptible state of mind.

Merely from a disturbed action of the nerves, and quite independently of all real structural or inflammatory disease, females frequently become distressed by more or less painful sensations fixed in one spot or shifting from one part to another. Violent pain in the head, as if a nail were driven into the forehead, is a very common hysterical symptom. Another frequent seat of the uneasiness or pain is the left side, just below the breast, and this pain is often attended with palpitation of the heart, and the patient is unable to lie on that side. Sometimes excruciating pain occupies the whole abdomen. In all such cases it will be found that the disease, simulated by the hysterical affection (whether it be of the head, chest, or abdomen, or of one of the large joints), cannot exist, since other symptoms essential to constitute it are absent. The pain of hysteria too, besides being frequently transitory and unfixed in its seat, has generally the peculiarity of being aggravated by the slightest touch of the skin, which is not the case with pain arising from inflammation. With this external tenderness there is frequently great tenderness along the course of the spine, and this is frequently greater at one particular spot.

Other symptoms of a decidedly hysterical or nervous nature will perhaps be present, or a true hysterical paroxysm may supervene. It is important to know that symptoms of almost every disease may be simulated by hysteria, which, though a troublesome affection for the sufferer, is unattended with danger. It is when real disease is present, and complicated with nervous or hysterical symptoms, that it requires the greatest acuteness of the physician to discern what proportion of the symptoms is of the latter kind, and what due to the more important affection.

Hysteria sometimes assumes the form of different paralytic affections the power of moving the arm, or the voice, may be lost. These phenomena may be of considerable duration, but are ultimately, and often suddenly, recovered from. The state of long-continued stupor which has received the name of "trance" is most commonly hysterical. Different spasmodic affections, as hiccough and spasm of the throat, preventing swallowing, not unfrequently occur in the hysterical state. Then, again, certain disordered states of the senses and mental faculties and feelings occur, as the consequence of uterine or sexual irritation, and are to be referred to hysteria. Such are somnambulism, some kinds of transitory monomania, and those peculiar perversions of the mind manifested in the desire to feign various diseases. The occasional occurrence of hysterical paroxysms, the irritable state of mind, the knowledge that the mind has been acted on in a way calculated to excite the affections, and the presence of other phenomena decidedly hysterical, will assist in detecting the true nature of all these cases.

There is certainly a peculiar state of the system which predisposes to the affections which we have thus cursorily described, for the causes by which they are excited have nothing peculiar in themselves. All the phenomena indicate a disordered state of the nervous system, and the exciting causes are such as act either through the medium of the body or the mind on that system. The susceptible state of the nervous system, which predisposes it when thus acted on to give rise to the various hysteric phenomena, is without doubt frequently connected with or kept up by an excited condition of the uterine system and the sexual feelings; with no system of organs and no feelings of the mind does the nervous system of females so much sympathise. This conclusion is confirmed by the fact of hysteria occurring in a great proportion of cases between the age of puberty and that at which the catamenia cease, during which period the uterus is in a state of greater activity than before and after it; and by the circumstance of its being at the commencement and termination of that period, when the uterine organs are undergoing the greatest changes, and the feelings of the mind connected with them are most disturbed, that the attacks of hysteria are most frequent and violent. It is from their supposed connection with particular states of the uterus that the attacks have derived their name. Other facts, however, show that a predisposed state of nervous system is necessary, for vascular excitement and structural disease of the uterus may exist without giving rise to hysteria; and that other functions, as those of the digestive organs, being disordered, may act on a susceptible person so as to aggravate the tendency to hysterical symptoms, or even excite them. In some females, having the requisite nervous susceptibility, a mere plethoric state of the body, without any affection of any special organ, will excite hysteria; the opposite state, deficiency of blood in the body, will have the same effect: anything, in fact, which throws the system of such irritable females out of the natural state, whether it act primarily on the body or mind, may give rise to nervous symptoms or hysteria. From the frequent occurrence of a deranged state of the blood and secretions, some forms of this disease have been called *anæmica*.

The most frequent exciting cause of the hysterical paroxysm is, perhaps, a sudden and intense emotion of the mind.

Treatment.—During a fit of hysteria, care should be taken to prevent the patient receiving injury from her head or hands striking against the floor or hard bodies, and to guard against the propensity to bite, by placing a folded cloth between the teeth. If the fit be slight, it may frequently be arrested by dashing cold water over the face, or by filling the mouth with something which has an unpleasant taste, as salt; or a stimulating scent may be held to the nostrils. If the paroxysm be more prolonged and violent, it will be proper, should the face be flushed and head hot, to apply wet cloths to the forehead, and to loosen all the dress about the neck and chest. If a continued stupor intervene, medical aid may be required. When there is less fulness about the head, small doses of stimulants, such as sal volatile in water, will be useful.

When the frequent return of the fits seems to depend on a full state of body, or on irritation, means calculated to remove these causes must be adopted. If an unnatural state of the uterine functions be suspected, these must be attended to. Frequently the sufferer from hysteria is feeble and bloodless, and in a state of general nervous debility; in such persons, all measures likely to strengthen the general health, proper diet, regular hours, change of air, and tonic medicines, should be put into practice. The preparations of iron are especially useful. The state of mind of the patient should, in these cases, be particularly regarded.

For the treatment of the pains and other anomalous nervous symptoms no rules can be laid down; they will frequently resist all modes of palliative treatment. The great principle, however, must not be forgotten of removing all causes which can re-act prejudicially on the nervous system or the general health.

The nervous susceptibility which predisposes to hysteria is, without doubt, frequently innate or constitutional; but it is certainly in many cases acquired; and it is often to be attributed, in a great measure, to the education of young females. "A luxurious and delicate mode of living and of rearing," says Dr. Copland; "a neglect of whatever promotes the powers of the constitution, especially of suitable exercise in the open air, and of early hours as to sleeping and rising; an over-refined mode of education, and the excitement of the imagination and of the emotions, to the neglect of the intellectual powers and moral sentiments; too great devotion to music, and the perusal of exciting novels; the various means by which the feelings are awakened and acute sensibility is promoted, whilst every manifestation of either is carefully concealed; and studied endeavours to dissemble desires which struggle to be expressed,—all serve, especially at a period when the powers of the mind and the conformation of the body are approaching development, to produce that state of the nervous system of which hysteria is one of the most frequent indications." The prevention of hysteria cannot certainly be hoped for until the education of females is directed more towards strengthening their body and improving the tone of their mind, so as to enable them to bear disappointments, and to control, not merely conceal, their passions.

I

I is a vowel which represents two very different sounds in different languages. In this country it denotes a rapid pronunciation of the diphthong *ai*. In French, Italian, and many other tongues, its sound is identical with that of the English *e*. In the series of the vowels established by the experiments of Mr. Willis [ALPHABET], *i*, as denoting the latter sound, lies at one of the two extremes. It is pronounced with the lips retracted so as to shorten the vocal tube, whereas the same organs are protruded to produce the sound represented at the other extremity by *u*. The various forms which have been used to represent the letter *i* may be seen in the article already quoted, cols. 240, 241. The character there given as used by the Phœnicians and early Greeks is somewhat complicated, and differs widely from the single stroke into which it eventually degenerated. In this last state it was the simplest of all the alphabetical characters, and was therefore well adapted to be the symbol of a small quantity. In this sense the terms a *jod* and an *iota* are still retained, *jod* being the Hebrew, *iota* the Greek name for the character.

The letter is interchangeable as follows:—

1. With the diphthongs *ai, oi, ei*. This may be seen most distinctly in the Latin language, where *alais, requairo, pueroi, puerois, nulloius, deico*, &c., were corrupted into *ālis, requīro, puerī, puerīs, nullīus, dīco*. In the same language, when one *i* was followed by another *i*, it was not uncommon to denote them by a single long *i*, as *tibīcen, Chīus, alīus* (gen.), *inscītia*, for *tibiicen, Chiius, aliius, insciitia*. In such cases it was a common practise to give greater length to the letter, thus, CHIVS.

2. The short *i* was interchangeable with nearly all the short vowels, more particularly in the penult syllables of polysyllabic words, which are very indistinctly pronounced. Thus the Greek *mēchănē* is in Latin *māchĭna*. In the same manner the Nomad races of North Africa are called by the Greeks *Nomades*, by the Romans *Numidae*. Again, ἄνεμος and *animus* are kindred words *Bonitas* must have been originally *bonotas*, and would have been written in Greek with a termination -οτης. Lastly, in a large number of words a short *u* degenerated into an *i*: as *maxŭmus, decŭmus, recŭpero, maritŭmus, scribŭmus* (compare *sŭmus*), into *maximus, decimus, recipero, maritimus, scribimus*. Even Cicero wrote all these words with a *u*, though our editions give an *i*.

3. A short *i* before *n* or *m* is not unfrequently in French changed into *ai* or *a*. Thus the Gallic town *Inculisma* is the origin of the name *Angoulême*: *vincere* is in French *vaincre*, &c.

4. In the same language the vowel *i* is changed into *oi* very commonly, as *sitis, soif; mi, moi; fides, foi; Ligeris, Loire*, &c., and this though the *i* in Latin be short.

5. *I* is often inserted in French or Spanish words before the vowel *e*: *miel, bien, vient*, &c., from the Latin *mel, bene, venit*.

6. The vowel *i* is often inserted after the vowels *a, o*, and *u* in the French language, particularly when a contraction has taken place, as *aimer, connoître, reduire*, from *amare, cognoscere, reducere*.

7. When the vowel *i* in the Latin language has a vowel after it, and is preceded by one of the consonants *p, b; t, d; c, g;* the derived languages have often a sibilant in the place of the former consonant. Thus *sapiam* is in French *sache*: *rabies, rage; ratio, raison; medius*, in Italian *mezzo* (compare the Greek μεσος). The double sound of *c* and *g* in our own language appears to have originated in this way.

8. A similar change occurs even in other cases, as *simia*, Fr. *singe*; *vindemia, vendange; lineus, linge*.

IAMBICS, a species of verse composed of a succession of iambi (˘ ¯), or equivalent feet, was freely used both by Greek and Latin poets. According to Aristotle ('De Poetic.'), the iambic measure was first employed in satirical poems, called *iambi*, which appear to have been represented or acted; since Plato ('De Rep.,' vii. 17) forbids boys to be spectators of iambi and comedies. The iambic is the most common metre in the Greek tragic poets. We are informed by Aristotle ('De Poetic.') that "originally the trochaic tetrameter was made use of, as better suited to the satyric and saltatorial genius of the poem at that time; but when the dialogue was formed, nature itself pointed out the proper metre; for the iambic is of all metres the most colloquial, as appears evidently from this fact, that our common conversation frequently falls into iambic verse, seldom into hexameter, and only when we depart from the usual melody of speech." (Twining's 'Transl.,' part i., c. 4.)

In the following table a list is given of the feet which may be admitted in the iambic metre in the Greek tragic poets, which is usually called the tragic trimeter acatalectic, because it consists of three entire metres, or six feet:—

1	2	3	4	5	6
˘ ¯	˘ ¯	˘ ¯	˘ ¯	˘ ¯	˘ ¯
˘ ˘ ˘	˘ ˘ ˘	˘ ˘ ˘	˘ ˘ ˘	˘ ˘ ˘	
¯ ¯		¯ ¯		¯ ¯	
¯ ˘ ˘		¯ ˘ ˘			
˘ ˘ ¯					

The anapæst in proper names is also introduced in every place of the verse except the last, with this general restriction,—that the anapæst should be contained in one word. The comic trimeter admits the same feet as the tragic, and also a dactyl in the fifth place, and an anapæst in common words in every place but the last.

Much of the beauty of the iambic trimeter depends upon the cæsura [CÆSURA], which usually occurs in the middle of the third or the middle of the fourth foot; as, for example:—

> *οἱ μὲν θέλοντες | εκβαλεῖν ἕδρας Κρόνον.*
> *ἱκτηρίοις κλάδοισιν | ἐξεστεμμένοι.*

One of these cæsuras may be considered as generally necessary; the cæsura in the middle of the third foot is much more common than in the middle of the fourth. There is also frequently a cæsura in the middle of the second or the middle of the fifth foot. When a line is divided in the middle of a verse with the elision of a short vowel, or of the little words δὲ, μὲ, σὲ, γὲ, τὲ, that division is called by prosodians the *quasi-cæsura*; as, for example:—

> *γυναιξὶ παρθένοις τ' | ἀπόβλεπτος μέτα.*

For an account of the other iambic metres employed by the Greek and Latin poets, see Hermann, 'Elementa Doctrinæ Metricæ.'

In English poetry the iambic metre is very common; as, for example:—

> "On Lin'den, whe'n the su'n was lo'w,
> All bloo'dless la'y th' untro'dden sno'w,
> And dar'k as win'ter wa's the flo'w," &c.

ICE. In several preceding articles of the present division of this Encyclopædia, reference has been made to the article now commenced for an account of an important fact among the properties of ice, which, from the investigation it has received at the hands of several of the most eminent living men of science, has been elevated almost to the position of a principle in physics. This is the property of REGELATION, by which liquefied ice remaining in contact with ice still solid, returns itself to the solid state.

In the year 1850, Professor Faraday invited attention, in a scientific point of view, to the fact that two pieces of moist ice, when placed in contact, will unite together, even when the surrounding temperature is such as to keep them in a thawing state. He showed experimentally that when two pieces of ice at 32° Fahr., with moistened surfaces, were placed in contact, they became cemented together by the freezing of the film of water between them. When the ice was below 32°, and therefore dry, no adhesion took place between the pieces; and he referred, in illustration of this point, to the well-known experiment of making a snowball. In frosty weather the dry particles of ice will scarcely cohere, but when the snow is in a thawing condition, it may be squeezed into a hard compact mass. He attributed this phenomenon to a property which he supposed ice to possess, of tending to solidify water in contact with it, and of tending more strongly to solidify a film or a particle of water, when the water has ice in contact with it on both sides, than when it has ice on only one side.

To these Professor Tyndall afterwards added the following illustrative facts. "On one of the warmest days of last July [1856], when the thermometer stood at upwards of 80° Fahr. in the shade, and above 100° in the sun, a pile of ice-blocks" being observed in a shop-window, the observer "thought it interesting to examine whether the pieces were united at their places of contact. Laying hold of the topmost block, the whole heap, consisting of several large lumps, was lifted bodily out of its vessel. Even at this high temperature the pieces were frozen together at the places of contact, though the ice all round these places had been melted away, leaving the lumps in some cases united by slender cylinders of the substance. A similar experiment may be made in water as hot as the hands can bear; two pieces of ice will freeze together, and sometimes continue so frozen in the hot water until, as in the case above mentioned, the melting of the ice around the points of contact leaves the pieces united by slender columns of the substance." 'Phil. Trans.,' 1857, p. 329.

Mr. Faraday, in his more recently published 'Experimental Researches in Chemistry and Physics' (being essentially a republication in a collective form of his papers on subjects belonging to those sciences, first published in the 'Philosophical Transactions,' and in several scientific journals), adheres to his original mode of accounting for the phenomenon he had observed, adopting the name Regelation, applied to it by Professor Tyndall. While alluding to certain views of Professor Forbes, which will presently be stated, as possibly being admissible as correct, and to an explanation offered by Professor James Thomson as being probably true in principle, and possibly having a correct bearing on the phenomena of regelation, he considers that the principle originally assumed by himself may after all be the sole cause of the effect. The principle he has in view, he then states as being, when more distinctly expressed, the following:—"In all uniform bodies, possessing cohesion, that is, being either in the liquid or the solid state, particles which are surrounded by other particles having the like state with themselves tend to preserve that state, even though subject to variations of temperature, either of elevation or depression, which if the particles were not so surrounded, would cause them instantly to change their condition." Referring to water in illustration, he says that it may be cooled many degrees below 32° Fahr., and still retain its liquid state; yet that if a piece of the same chemical substance—ice, at a higher temperature, be introduced, the cold water freezes and becomes warm. He points out that it is certainly not the change of temperature which causes the freezing, for the ice introduced is warmer than the water; and he says he assumes that it is the difference in the condition of cohesion existing on the different sides of the changing particles which sets them free and causes the change. Exemplifying, in another direction, the principle he is propounding, he refers to the fact that water may be exalted to the temperature of 270° Fahr., at the ordinary pressure of the atmosphere, and yet remain water, but that the introduction of the smallest particle of air or steam will cause it to explode, and at the same time to fall in temperature. He further alludes to numerous other substances, such as acetic acid, sulphur, phosphorus, alcohol, sulphuric acid, ether, and camphine, which manifest like phenomena at their freezing or boiling points to those referred to as occurring with the substance of water, ice, and steam; and he adverts to the observed fact, that the contact of extraneous substances with the particles of a fluid usually sets these particles free to change their state, in consequence, he says, of the cohesion between them and the fluid being imperfect; and he instances that glass will permit water to boil in contact with it at 212° Fahr., or by preparation can be made so that water will remain in contact with it at 270° Fahr., without going off into steam, but that an ordinary piece of glass will set the water off at once to freeze.

Professor Faraday afterwards comes to a point in his reasoning which he admits may be considered as an assumption. It is, "that many particles in a given state exert a greater sum of their peculiar cohesive force upon a given particle of the like substance in another state than few can do; and that as a consequence a water particle with ice on one side and water on the other, is not so apt to become solid as with ice on both sides; also that a particle of ice at the surface of a mass [of ice] in water is not so apt to remain ice as when, being within the mass, there is ice on all sides, temperature remaining the same."

"This supposition," Professor James Thomson observes, "evidently contains two very distinct hypotheses. The former, which has to do with ice and water present together, I certainly do regard as an assumption unsupported by any of the phenomena which Mr. Faraday has adduced. The other, which has to do with a particle of ice in the middle of continuous ice, and which assumes that it will not so readily change to water, as another particle of ice in contact with water, I think is to be accepted as probably true. I think the general bearing of all the phenomena he has adduced, is to show that the particles of a substance when existing all in one state only, and in continuous contact with one another, or in contact only under special circumstances with other substances, experience *a difficulty of making a beginning of their change of state,* whether from liquid to solid, or from liquid to gaseous, or probably also from solid to liquid; but I do not think anything has been adduced showing a like difficulty as to their undergoing a change of state when the substance is present in the two states already, or when a beginning of the change has already been made. I think that when water and ice are present together, their freedom to change their state on the slightest addition or abstraction of heat, or the slightest change of pressure, is perfect. I therefore cannot admit the validity of Mr. Faraday's mode of accounting for the phenomena of regelation."

The view of the subject involved in the statement of Professors Faraday and Tyndall, given above (before the former had enunciated his own views in the more extended form), was adopted by the latter physicist as the basis of a theory by which he proposed to explain the viscosity or plasticity of ice previously known to be the quality in glaciers [Glaciers, in Nat. Hist. Div.], in virtue of which their motion down their valleys is produced by gravitation; but which he described as being not true viscosity, but, in brief, as the result of fracture, change of position of the fractured parts, and regelation of those parts in their new position; the term *regelation* being now first given to the fact, the scientific importance of which had been originally pointed out by Faraday.* Professor James Thomson, Queen's College, Belfast, whose first express contribution to the subject we now have to record, conceiving Professor Tyndall's theory of the viscosity of glacier ice to be wrong, made public a theory of his own involving a different view of the nature of the phenomenon of regelation. This, as sketched in outline by himself, is as follows:—If to a mass of ice at its melting-point, pressures tending to change its form be applied, there will be a continual succession of pressures applied to particular parts—liquefaction occurring in those parts through the lowering of the melting-point by pressure—(experimentally demonstrated in 1850 by Professor William Thomson, of Glasgow, his brother)—evolution of the cold by which the so melted portions had been held in the frozen state,—dispersion of the water so produced in such directions as will afford relief to the pressure,—and recongelation, by the cold previously evolved, of the water on its being relieved from this pressure: and the cycle of operations will then begin again; for the parts recongealed, after having been melted, must in their turn, through the yielding of other parts, receive pressures from the applied forces, thereby to be again liquefied and to proceed through successive operations as before.†

Professor James D. Forbes adopts the view of Persoz, that the dissolution of ice is a *gradual,* not a *sudden,* process, and so far resembles the tardy liquefaction of fatty bodies, or of the metals, which in melting pass through intermediate stages of softness or viscosity.‡ He thinks that ice must essentially be colder than water in contact with it; that between the ice and the water there is a film varying in local temperature from side to side, which may be called plastic ice, or viscid water; and that through this film heat must be constantly passing from the water to the ice, and the ice must be wasting away, though the water be what is called *ice-cold.* On this, Professor J. Thomson thus comments:—"There is a manifest difficulty in conceiving the possibility of the state of things here described; and I cannot help thinking that Professor Forbes has been himself in some degree sensible of the difficulty; for in a note of later date by a few months than the paper itself [in which the view had been given], he amends the expression of his idea by a statement to the effect that, if a small quantity of water be inclosed in a cavity in ice, it will undergo a gradual *regelation* [§],—that is, that the ice will in this case be gradually increased instead of wasted." In reference to the first case, Professor J. Thomson asks, "What becomes of the cold of the ice, supposing there to be no communication with external objects, by which heat might be added to or taken from the water and ice jointly considered? Does it go into the water and produce viscidity beyond the limit of the assumed thin film of viscid water at the surface of the ice? Precisely a corresponding question may be put relatively to the second case,—that of the large quantity of ice inclosing a small quantity of water, in which the reverse process is assumed to occur. Next, let an intermediate case be considered, that of a medium quantity of ice, and in which no heat nor cold, practically speaking, is communicated to the water or the ice from surrounding objects. This, it is to be observed, is no mere theoretical case, but a perfectly feasible one. The result, evidently, if the previously described theories be correct, ought to be that the mixture of ice and water ought to pass into the state of uniform viscidity. Professor Forbes' own words distinctly deny the permanence of the water and ice in contact in their two separate states; for he says, 'Bodies of different temperatures cannot continue so without interaction. The water must give off heat to the ice; but it spends it in an insignificant thaw at the surface, *which, therefore, wastes even though the water be what is called ice-cold.'* Now, the conclusion arrived at, namely, that a quantity of viscid water could be produced in the manner described, is, I am satisfied, quite contrary to all experience. No person has ever, by any peculiar application of heat to, or withdrawal of heat from, a quantity of water, rendered it visibly and tangibly viscid. We even know that water may be cooled much below the ordinary freezing point and yet remain fluid."

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* The terms *fracture* and *regelation,* Professor J. Thomson remarks, then came to be the brief expression of Professor Tyndall's idea of the plasticity of ice. But the former, whose views we are about to give in the text, observes on the nomenclature of the process, "I suppose the term regelation has been given by Professor Tyndall as denoting the second, or mending stage in his theory of '*fracture* and *regelation.*' Congelation would seem to me the more proper word to use after fracture, as *regelation* implies previous melting. If my theory of *melting by pressure and freezing again by relief of pressure* be admitted, then the term regelation will come to be quite suitable for a part of the process of the union of the two pieces of ice, though not for the whole, which then ought to be designated as the process of *melting* and *regelation.*" 'Proceedings of the Royal Society' (vol. x.) for Nov. 24, 1859, p. 154, note. It may be remarked on this, however, that while the latter phrase may be required in discussing the phenomena of glaciers, as the word *re*-gelation itself implies that a previous frozen state has existed, it would appear to be sufficient in designating simply the physical process to which it was originally applied.

† In explanation of the simplest case of regelation, Professor J. Thomson expressed himself in the following manner in a communication to the British Association, in 1857:—"The two pieces of ice (at 32°) on being pressed together at the point of contact, will, at that place, in virtue of the pressure, be in part liquefied and reduced in temperature, and the cold evolved in their liquefaction will cause some of the liquid film intervening between the two masses to freeze."

‡ Sir J. F. W. Herschel, when he terms regelation "a sort of welding" (Hail), appears to concur with this view.

[§ This use of the term *regelation* we conceive to be at once inaccurate, and tending to ambiguity. The water in this case need not have been frozen before; and to call its solidification, by the effect of the contiguous ice, regelation, is erroneously to extend the application of that term to all cases in which water, however originally resulting, is frozen by the contact of ice.]

Professor Forbes regards Mr. Faraday's fact of regelation as being one which receives its proper explanation through his theory described above; and, in confirmation of the supposition that ice has a tendency to solidify a film of water in contact with it, and in opposition to the theory given by Professor J. Thomson, that the regelation is a consequence of the lowering of the melting-point in parts pressed together, he adduces an experiment made by himself. He states that mere contact without pressure is sufficient to produce the union of two pieces of moist ice, and then describes as follows his experiment by which he supposes that this is proved:—"Two slabs of ice, having their corresponding surfaces ground tolerably flat, were suspended in an inhabited room upon a horizontal glass rod passing through two holes in the plates of ice, so that the plane of the plates was vertical. Contact of the even surfaces was obtained by means of two very weak pieces of watch-spring. In an hour and a half the cohesion was so complete that, when violently broken in pieces, many portions of the plates (which had each a surface of twenty or more square inches) continued united; in fact, it appeared as complete as in another experiment, where similar surfaces were pressed together by weights." He concludes that the effect of pressure in assisting "regelation" is principally or solely due to the larger surfaces of contact obtained by the moulding of the surfaces to one another.

Professor J. Thomson has himself repeated this experiment, and has found the results described by Professor Forbes to be fully verified. It was not even necessary to apply the weak pieces of watch-spring, as he found that the pieces of ice, on being merely suspended on the glass rod in contact, would unite themselves strongly in a few hours. This fact Professor Thomson explains by the capillary forces of the film of interposed water, as follows:—Firstly, the film of water between the two slabs—being held up against gravity by the capillary tension or contractile force of its free upper surface, and being distended besides, against the atmospheric pressure, by the same contractile force of its free surface round its whole perimeter, except for a very small space at bottom, from which water trickles away, or is on the point of trickling away—exists under a pressure which, though increasing from above downwards, is everywhere, except at that little space at bottom, less than the atmospheric pressure. Hence the two slabs are urged towards one another by the excess of the external atmospheric pressure above the internal water pressure, and are thus pressed against one another at their places of contact by a force quite notable in its amount. If, for instance, between the two slabs there be a film of water of such size and form as might be represented by a film one inch square, with its upper and lower edges horizontal, and with water trickling from its lower edge, it is easy to show that the slabs will be pressed together by a force equal to the weight of half a cubic inch of water. But so small a film as this would form itself, even if the two surfaces of the ice were only very imperfectly fitted to one other. If, again, by better fitting, a film be produced of such size and form as may be represented by a square film with its sides 4 inches each, the slabs will be urged together by a force equal to the weight of half a cube of water, of which the side is 4 inches; that is, the weight of 32 cubic inches of water, or 1·15 pound, which is a very considerable force. Secondly, the film of water existing, as it does, under less than atmospheric pressure, has its freezing-point raised in virtue of the reduced pressure. Much more, he adds, will it freeze in virtue of cold given out in the melting by pressure of the ice at the points of contact, where, from the first two causes stated above, the two slabs are urged against one another.

The different explanations and interpretations which have been enunciated of the facts of regelation have been stated in this article partly in the words of their authors, and partly in those of Professor James Thomson, by whom the subject has been most recently treated. References to some of the original memoirs will be found in his paper in the 'Proceedings of the Royal Society' (vol. x.), for Nov. 24, 1859, pp. 152–160; and others will be indicated in the sequel of this article.

It is manifest that the subject of regelation is one of great importance in physics and in the history of nature, being connected with that of the mutual relations of the different states of aggregation in which the same species of ponderable matter—the same substance, chemically speaking—can exist, and also with those "hidden and unseen motions," to use the language of Boyle, by which the molecular condition of such matter is perpetually changing. Some bodies, the equilibrium of the proximate elements of which is very unstable, present, in the solid state, phenomena, seemingly at least, analogous to those presented by water, and others in their alternation between the liquid and the solid states. Of these, glass is an example, and the now well-known fact of the incorporation into one mass of two or more plates of (plate-) glass, the polished surfaces of which have been placed in close contact with each other, presents a curious parallel to the incorporation into one of several slabs or other separate portions of ice by regelation, as taking place in the experiments described in this article, and to determine in what manner these two subjects are related to each other would appear to deserve careful investigation. The principal facts, so far as glass is concerned, with the bearings on molecular philosophy they appeared to possess before the phenomena of regelation had been scientifically considered, will be found in the abstracts of two lectures on that substance delivered by Mr. Brayley before the Pharmaceutical Society of London in 1845, published in the 'Pharmaceutical Journal' (vol. v.) for August and October of that year.

In a paper on the Physical Properties of Ice, Professor Tyndall has shown that when a sunbeam traverses a mass of ice, the latter melts at innumerable points in the track of the beam, and that each portion melted assumes the form, not of a globule, but of a flower of six petals. The planes in which these flowers are formed are independent of the shape of the mass, and of the direction of the beam through it; they are always formed *parallel to the surface of freezing*. This, he observes is a natural consequence of the manner in which the particles of ice are set together by the crystallizing force. By the slow abstraction of heat from water in the process of freezing, its particles build themselves into these little stars, and by the introduction of heat into a mass so built, the architecture is taken down in a reverse order. In watching the formation of artificial ice, by the machine of Mr. Harrison (noticed under FREEZING-APPARATUS), Professor Tyndall has seen little solid stars formed, which were the exact counterparts of the little liquid stars formed by melting. 'Phil. Trans.' 1858, pp. 211–227; Ib. 1859, pp. 298, 299. Appended to the former paper is a letter from Professor Faraday on the irregular fusibility of ice.

Another important part of the history of ice is its production on the bed of rivers, when it receives the name of *Ground-ice*, *Bottom-ice*, and *Ground-gru*; the *Glace-du-fond* of the French, and the *Grund-eis* of the Germans. It is generally imagined that rivers freeze only at the surface; this however is not the fact, ice being frequently formed at the bottom of running water. Thus, according to the late Rev. Dr. Farquharson, F.R.S., the phenomenon is so common, and so well known in certain parts of Aberdeenshire, that the inhabitants have given it the name of Ground-gru, a name which that gentleman has adopted in his paper on the subject in the 'Philosophical Transactions' for 1835, p. 329. Gru is the name by which the people of Aberdeenshire designate snow saturated with or swimming in water; and as the ice formed at the bottom of rivers very nearly resembles that in appearance, a better name than Ground-gru could hardly be given, though it would be more precise to call it subaqueous ice, in contradistinction to that found at the surface, and because the term ground-ice, which this formation has also received, has been sometimes given to the ice occasionally met with at certain depths in the ground in northern countries.

Common, however, as may be the phenomenon of subaqueous ice, and although it has been noticed at various times, it has but lately attracted the serious attention of observers. Ireland, in his 'Picturesque Views of the River Thames,' published in 1792, 2 vols. 8vo., mentions the ground-ice of that river, and on the subject quotes Dr. Plott, who says, "The watermen frequently meet the ice-meers, or cakes of ice, in their rise, and sometimes in the underside enclosing stones and gravel brought up by them *ab imo*."

M. Arago published an interesting paper on the subject in the 'Annuaire du Bureau des Longitudes' for 1833, in which he mentions the following observations made on ground-ice:—In the Thames, by Hales, in 1730; in the river Déome, department of Ardèche, France, by Desmarets, in 1780; in the Elbe, by M. Braun, in 1788; in the Teine, Herefordshire, by Mr. T. A. Knight, in 1816; in the Canal de la Birze, near Bâle, by M. Mérian, in 1823; in the Aar, at Soleure, by M. Hugi, in 1827 and 1829; in the Rhine, at Strasburg, by Professor Fargeau, in 1829; and in the Seine, by M. Duhamel, in 1830. More lately still, Colonel Jackson, in a paper on the congelation of the Neva, published in the 5th volume of the 'Journal of the Royal Geographical Society,' mentions the formation of ground-gru at the bottom of that river; and in the 6th volume of the same journal there is a paper expressly on the ice formed at the bottom of the Siberian rivers. The Rev. Mr. Eisdale has, in the 'Edinburgh New Philosophical Journal,' vol. xvii., p. 167, a paper on ground-ice; and, finally, Dr. Farquharson, as already mentioned, published his observations on the ground-gru of the rivers Don and Leochal, in Aberdeenshire.

Almost all who have written on ground-gru have endeavoured to account for its formation, though no explanation yet given is perfectly satisfactory. Dr. Farquharson, whose paper contains an original investigation of the subject, says it is the result of radiation, and endeavours to substantiate his reasoning upon the principles of the formation of dew. It was remarked in this article, as originally published, that he seems to forget that Dr. Wells maintains expressly that wind and shade are alike obstacles to radiation; and that consequently a body of moving water so deep as to be impervious to light, and particularly when covered, as in the case of the Neva, with a sheet of ice three feet thick, and as much more of snow, must present an insurmountable obstacle to the radiation of heat from the bottom of the river. This objection, however, is unsound, and is removed, as in many other instances of the supposed insufficiency of the principle of radiation to account for depression of temperature, by an adequate consideration of the entire series of the phenomena concerned. It is true that the thick sheet of ice and its covering of snow will present an obstacle to the direct radiation of heat into space from the bed of the river, though they themselves will have such radiation above. But the bed of the river, at a comparatively high temperature, will suffer refrigeration by the radiation of its heat to the ice on the surface of the river, and may thus (and if there be time enough must necessarily thus) be cooled eventually to the freezing point, and so effect the formation of the ground-ice. A familiar and readily intelligible illustration of this will be found in an observation of Dr. Joseph D. Hooker, which occurs in the invaluable collection of physical facts presented by his 'Himalayan Journals,' and already cited in the article Dew. When in the narrow valleys of East Nepal, in the month of November, and at the elevation of 8000 feet, the nights were so brilliant, and the radiation from the earth and bodies upon it consequently so powerful, that the upper blanket of his bed became coated with dew, from the rapid abstraction of heat by its radiation to the tarpaulin of his tent, itself frozen by it's own radiation to the sky. The direct radiation of the blanket to the sky was prevented by the tarpaulin, but this did not prevent the conversion of the aqueous vapour in contact with the blanket into dew. In this case, the frozen tarpaulin corresponded in its action to the surface-ice of the river, the blanket to the river-bed, and the dew upon it to the ground-ice. Had the exposure been longer continued, or the temperature of the whole system of radiating bodies been lower, hoar-frost instead of dew would have been formed, and the parallel would then have been perfect,—according to Dr. Farquharson's view of the origin of ground-ice.

Mr. Eisdale thinks ground-ice is the result of frozen spiculæ from the atmosphere, analogous to hoar-frost, falling into the river, and there forming *nuclei*, around which the water freezes at the bottom; but this is quite inadmissible. M. Arago's explanation in part, and the very simple fact that water, when at 32° of Fahr., if at rest, or in very slow motion (which is the case at the bottom of rivers), will freeze, seem among the most natural ways of accounting for the formation of ground-gru. M. Arago attributes the formation to three circumstances—1st, the inversion, by the motion of the current, of the hydrostatic order, by which the water at the surface cooled by the colder air, and which at all points of the temperature of water under 39° Fahr. would, in still water, continue to float on the surface, is mixed with the warmer water below; and thus the whole body of water to the bottom is cooled alike by a mechanical action of the stream; 2nd, the aptitude to the formation of crystals of ice on the stones and asperities of the bottom in the water wholly cooled to 32°, similar to the readiness with which crystals form on pointed and rough bodies in a saturated saline solution; 3rd, the existence of a less impediment to the formation of crystals in the slower motion of the water at the bottom than in the more rapid one near or at the surface. But, as has been said, no explanation yet given is quite satisfactory, and the phenomenon yet remains to be studied under all the variety of circumstances which may attend it. A knowledge of the temperature of the water at different depths is most essential to a just appreciation of the real cause of the phenomenon.

Ground-gru differs materially from surface-ice. Dr. Farquharson describes it as having "the aspect of the aggregated masses of snow, as they are seen floating in rivers during a heavy snow-shower; but on taking it out of the water, it is found to be of a much firmer consistence than these: it is a cavernous mass of various sized, but all small, pieces or crystals of ice, adhering together in an apparently irregular manner by their sides, or angles, or points, promiscuously; the adhesion varies according to circumstances." This corresponds precisely with what is stated by Col. Jackson to have been observed by him in the Neva at St. Petersburg. Dr. Farquharson says, that when it begins to form at the bottom, it aggregates in forms somewhat resembling little hearts of cauliflower. Mr. Weitz, author of the paper in the 'Journal of the Geographical Society' on the ground-gru of the Siberian rivers, says that which he noticed at the bottom of the Kann (an affluent of the Jenissel), 40 versts from Krasnojarsk, was of a greenish tinge, and resembled patches of the *confervoidæ*. From these facts we conclude that though the appearances of the ground-gru may vary with circumstances, it is in all cases essentially different from the solid compact sheets of surface-ice.

[Dew; Freezing; Hail; Hoar-Frost; Meteorology; Snow; Water.]

ICEBERG. [Sea.]

ICE-HOUSES AND ICE-TRADE. Considering ice as an article of commerce, one of the most important points connected with it is the adoption of means for preventing the substance from melting away in hot weather. Ice-houses are expressly constructed to this end. Such structures are not only useful for preserving ice which is to be applied to the cooling of liquors, or to the preparation of articles of confectionary, but also as affording the most ready if not the most effectual means known for keeping meat, fish, game, vegetables, and fruit sweet and fresh in hot weather. Although these important conveniences are rarely to be found among the buildings of an English farm, they are frequent in those of North America, and might be advantageously introduced in this country, especially upon such farms as are connected with inns.

One of the simplest modes of preserving ice consists in enveloping it in a great quantity of straw, above the surface of the ground, in such a position that moisture, which is even more injurious than heat, may drain off freely. For this purpose the ground should be raised in the form of a flattened cone, upon which should be laid a stratum of faggots. Straw is laid upon the faggots to the thickness of a foot or more, and the ice is piled upon it in a compact conical mass, the larger the better. Over the ice is laid first about a foot thickness of straw; then faggot-wood to a further thickness of two feet, the interstices of which have the effect of keeping a stratum of confined air round about the pile of ice; and, finally, two or three feet of straw arranged as a thatch.

An underground ice-house may be simply a large cellar, with hollow or double walls, floor, roof, and doors, and furnished with a trapped drain to allow the escape of such water as may be produced by a partial thaw, without admitting any air. Such ice-houses are usually formed in the shape of an inverted cone, which is considered the most advantageous because it keeps the ice more compactly together than any other form, and because, in case of any thaw taking place, the remaining ice will naturally slip down, so as to keep the mass solid. In all cases it is well to interpose a layer of straw, reeds, or chaff (the last named is preferred to straw in Italy, where it is used for packing ice for travelling) between the walls and the ice; and by the use of faggots as well as straw any perfectly dry cellar in a suitable situation may be used as an ice-house. In some situations a sufficient degree of hollowness in the walls may be produced by the adoption of the plan of building with bricks on edge, or by some similar contrivance. One mode of building hollow walls which may be thus applied consists in the use of half-bricks divided longitudinally, as stretchers, leaving a space equal to the full width of a brick between them. Hollow floors for ice-houses may be constructed in various ways, with bricks on edge and tiles or flags. Whatever be the construction of the ice-house itself, there should be no opening by which it can communicate with the external air excepting through the entrance passage, which is usually at least two or three yards long, and furnished with two, three, four, or more doors, of which not more than one must be opened at a time. Where the difficulty of excluding external temperature is very great, treble walls, roofs, and floors may be used; and the entrance-passage may be made crooked, with a door at every turn.

Loudon gives a ground-plan and section of a complete ice-house of approved construction, of the inverted conical shape, with an arched roof, which it is proposed to cover with two or three feet of earth, or more in hot climates, over which he suggests the propriety of training ivy, for the sake of excluding solar heat. In this design a small pump is shown communicating with a well in the drain of the ice-house, for the purpose of raising the thaw-water for drinking or other use. Ure describes a similar structure, but with solid walls and a conical roof of timber, which may be simply thatched, or covered with brickwork and thatched, and which should have a gutter round it to collect and conduct to a distance all rain that falls upon it. In Gordon's plan the excavation is made considerably larger than the ice-house, which consists of a framework of strong timbers, roughly boarded outside, and lined with straw set on end and confined by laths nailed to the timbers. The conical roof is thatched with straw or heath, and the space between the outer boarding and the surface of the excavation is filled with heath, brushwood, or fir-tops, and neatly thatched or turfed over. In some situations simple excavations in calcareous soils, with a long circuitous passage by way of approach, are used instead of more regular ice-houses.

In filling an ice-house, the ice should be broken with mallets to a coarse powder, and well rammed down as it is thrown into the ice-well; its upper surface being kept of a concave shape, and a little water being occasionally added to fill up all interstices, and to facilitate the congelation of the whole into a solid mass. A better method is to sprinkle the ice with water saturated with salt, at the rate of a pound of salt to a gallon of water. This salt and water may be applied by a common watering-pot upon the surface of the ice at intervals of two feet from bottom to top of the mass, an extra quantity being poured on when the filling is completed. By this means the ice becomes so firmly compacted as to need the force of a pickaxe to break it up, even in the heat of summer. Snow is occasionally preserved in a similar manner to ice, it being carefully compressed into a solid mass. In Portugal and some other countries, when the snow has been collected in a deep gulf, some grass or green sods, covered with dung from the sheep-pens, is thrown over it; and under this covering the snow is so well preserved that it may be taken up and transported to a considerable distance throughout the summer.

An ice-box, or sort of portable ice-house, is occasionally used. It consists of an inner and outer casing, six inches apart, the interval between which is filled with burnt cork reduced to powder, this being found to possess higher non-conducting properties than the charcoal of wood. The lid is double, and is filled with the same substance; and it is made perfectly air-tight by means of projecting ledges, which, when shut, dip into a gutter filled with water. Ice may be preserved for several weeks in such a box, in which also bottles, dishes, &c., may be placed. Similar to this contrivance is the American ice-safe, introduced a few years ago into this country.

The French, in 1859, constructed an extensive range of ice-houses in the Bois de Boulogne, between the Auteuil railway and the fortifications of Paris. During the hard frost of December in that year, 250 carts were employed for 10 days in conveying ice to these buildings.

A remarkable traffic has sprung up in America, namely, the transport of ice to various parts of the world. In the East Indies the artificial formation of ice has been long carried on, as the only means of cooling beverages and food. The ground near Hoogly, about 40 miles from Calcutta, is formed into shallow troughs; into these troughs, on a layer of straw, are placed pans of porous earthenware. Shortly before midnight in the winter months, and when the wind happens to be blowing from the north-west, a little water is poured into each vessel or pan; and if all the circumstances are favourable, a film of ice is found in each pan on the following morning, which ice is collected and stored with the utmost care. The selling price of this ice at Calcutta was formerly about sixpence per pound; but the Calcutta inhabitants were surprised by the arrival, in 1833, of a ship from the United States, laden entirely with ice, which was offered for sale at three-pence per pound, and was understood to yield a good profit, even after paying all the expenses of a long voyage. Since then the price has been much lowered, and ice has become a regular article of shipment from America. The idea of this trade had occurred to a Boston merchant, Mr. Tudor, twenty years earlier; but it was only by much patience and perseverance that he overcame the various difficulties.

The trade is now chiefly in the hands of the Wenham Lake Company. This company purchased a lake of pure water, and the surrounding land, at Wenham, about eighteen miles from Boston; they built storehouses, and formed a railway from Wenham to Boston. The lake is very deep, and is supplied solely by springs, which issue from its bed. During winter the ice which forms on it is very thick, clear, and compact. When the ice is about a foot thick, a number of men, horses, and machines are set to work. The ice is first swept scrupulously clean; an *ice-plane* is drawn over it, to cut away a layer of loose or imperfect ice; an *ice-plough* is drawn over it, to cut a groove across the lake; and other machines are successively employed, until the ice is removed from the lake, in solid blocks weighing from one to two cwts. each. They take two acres of lake surface into operation at one time; this will yield, at the average thickness, about two thousand tons of ice; and forty men, assisted by twelve horses, will cut and stow four hundred tons of this in a day. The company's store-house, near the lake, is built of wood, and has double walls two feet apart: the intervening space being filled with sawdust; twenty thousand tons of ice can be stored in this building at one time. The company convey the ice to Boston on their own railway, and thence transmit it to various parts of the world. Large store-houses have been formed in many parts of the United States, as well as in London and Liverpool. So many are the establishments now engaged in this trade, and so important has it become, that the ice-farms of the states of Massachusetts and New York are reputed to be equal in commercial value to the rice farms of Georgia. Boston is the great storehouse, containing sometimes as much as 300,000 tons of ice in store at once. About 10,000 persons altogether are supposed to be concerned in and with the ice-trade of America, and about 6,000,000 dollars of invested capital.

A curious project was started a few years ago, for sending a steamboat to Newfoundland, to *tow home an iceberg*; an iceberg of 10,000 tons would, it was conceived, pay the expenses and yield a good profit.

There have been many projects for producing ice artificially—by rarefaction, by evaporation, by the contact of freezing mixtures, and by other means; some of which are described in the articles Freezing; Freezing Apparatus; Freezing Mixtures.

ICELAND MOSS, botanically *Cetraria Islandica: Medical Properties of.*—This lichen, commonly termed Iceland moss, though native of the higher mountains of the northern part of Britain, is procured mostly from Norway and Iceland, on the lava of the west coast of which latter country it abounds and attains a large size. It is imported through Hamburg. "The thallus is erect, tufted, olive-brown, paler on one side, laciniated, channelled, and dentato-ciliate; the fertile lacinia very broad; apothecia brown, appressed, flat, with an elevated border." (Hooker.) The apothecia are very rarely developed on the thallus in Britain, save on the mountains of Ben-na-bord in Aberdeenshire, and the imported specimens rarely have them, probably from being gathered in a young state; for this lichen is too important an article of food in northern countries to be allowed to grow to maturity. When dry, it has scarcely any odour, and the taste is bitter and unpleasant. The powder or flour is of a whitish gray.

The analysis of Berzelius gives as its constituents—starchy matter of a peculiar kind (*lichenin*), 44·6; bitter principle (*cetrarin*), 3·0; uncrystallisable sugar, 3·6; chlorophylle, 1·6; extractive matter, 7·0; gum, 3·7; bitartrate of potass, and tartrate of lime, along with phosphate of lime, 1·9; amylaceous fibrin, 36·2; and inulin.

The bitter principle, or cetrarin, may be separated by digesting the lichen in cold water containing 1-16th of carbonate of potass (some affirm 1-300th to be sufficient) for twenty-four hours. The whole is then thrown upon a sieve, and the liquid drained off. This liquid, when evaporated, yields a whitish principle, extremely bitter, very soluble in alcohol, particularly when boiling, and ether; sparingly so in water, volatile oils, and creasote. This principle may also be separated by animal charcoal, according to Peretti. ('Annalen der Pharmacie,' vi. p. 344.) If the lichen be steeped in distilled water, and once or twice heated in the water up to 180° Fahr., most of the bitterness is removed. (Pereira.) When this is removed, the starchy matter differs little from wheat-flour in nutritive properties, though Olasson asserts that a soup prepared with it is twice as nutritious as one made with flour. (Sparmann, 'Voyage,' iii. p. 129, note.) Certain it is that the inhabitants of Norway, Lapland, and above all, of Iceland, use it extensively as an alimentary substance, the latter regarding it as the gift of "a bountiful Providence, which sends them bread out of the very stones." Dr. Henderson ('Tour in Iceland') says that a porridge made of this lichen-flour is to a foreigner not only the most wholesome, but the most palatable, of all the articles of Icelandic diet. It is submitted to no other preparation than repeated steepings in cold water, drying, and powdering; after which it is either made into cakes or boiled in milk. Unless it be steeped, it is both offensively bitter, and also to many persons purgative; hence it has been called *lichen catharticus.* (Borrichius, 'Act. Hafnien.,' 1671, p. 126.) But cattle turned out to browse on it in spring, though at first purged, ultimately become fat. (Boerhaave.) Owing to its intensely bitter taste, as it had not been previously steeped, Sir John Franklin, even when pressed by hunger, could not use it, though the tripe de roche suited well. ('First Journey to Shores of Polar Sea,' 4to., p. 413, 414.)

The excellence of Iceland moss depends upon its freshness and freedom from accidental impurities, which should be carefully removed before it is used. In its natural state, that is, while still containing the bitter principle, it is tonic, stomachic, febrifuge, demulcent, and nutritious. It has acquired a high reputation, not merely as an article of diet, but as a medicinal agent in consumption and chronic diarrhœas, and dysenteries devoid of inflammatory states of the intestines. To obtain benefit from it, the use of it must be persisted in for a long time. This constitutes at once a difficulty in the employment of it, and casts a doubt on the exact nature of the cases in which it is said to have proved serviceable. The unpleasantness of the bitter it contains renders it unpalatable to most persons, and also its heating qualities unfit it for those who have either much general fever, or a state of sub-acute inflammation of the stomach, a very frequent condition in genuine phthisis pulmonalis. Hence there is every reason for suspecting that in the instances where it has been used for a long time and proved beneficial, the disease was chronic bronchitis, in which bitters and demulcents are extremely useful. To disguise the disagreeable flavour many expedients have been had recourse to, such as uniting it with chocolate or cocoa, and flavouring it with orange-flower water, &c. (A full account of these may be found in Hufeland's 'Journal,' August, 1824, p. 126, from the pen of Dr. Oppert. Many formulæ may be found in Geiger, 'Pharmacopœia Universalis.') The only officinal form in Britain is the decoction, which is frequently made the vehicle of medicinal agents. Cetrarin has been given in a separate form as a succedaneum for cinchona bark, and, like many other very bitter articles, is of considerable efficiency in agues. Many substitutes for Iceland moss have been proposed; one of the best of which is the Carrageen or Irish moss (*Fucus crispus*). This, when the brackish taste is lessened by repeated steepings in cold water, forms an excellent jelly, much relished by consumptive patients, and much cheaper than any other. The *Sticta pulmonacea*, or lung-wort, is of unquestionable efficacy in some cases of asthma. But none are so palatable as the Ceylon moss (*Fucus amylaceus*). This can be procured not only from Ceylon, but abundantly from the east coast of Bengal. In the form of jelly, soup, lozenges, or other mode of preparation, it not only agrees better, but is more relished than any jelly, either animal or vegetable. It is to be hoped that it will become a regular article of commerce.

All the Iceland moss imported into Britain is not used for medicinal purposes; much is employed in baking ship-biscuits, as those into the composition of which it enters are said not to be attacked by worms, or suffer much from sea-water. In Saxony, in time of scarcity, it is advantageously added to wheaten flour. In some countries it is employed in brewings.

ICHNOGRAPHY (from *ιχνος* and *γραφη*), a representation of the groundwork of a building. The *ichnography* of a building is, in fact, what is more commonly called the plan, or ground-plan: as the *orthography* is the elevation.

ICHTHIN. An albuminous principle extracted from the yolk of the eggs of cartilaginous fishes, such as the ray fish. It has the appearance of white transparent soft grains, insoluble in alcohol, water, and ether. Hydrochloric acid dissolves it without violet coloration, which distinguishes ichthin from albumen. It contains:—

Carbon	50·9
Hydrogen	6·7
Nitrogen	14·7
Phosphorus (?)	1·9

ICHTHIDIN. [Ichthulin.]

ICHTHULIN. An albuminoid substance found along with *ichthidin* in the roe of certain species of fish. It is precipitated by the addition of water to the expressed fluid of the roe. Ichthulin when first precipitated is viscous like gluten, but it afterwards becomes pulverulent. It contains:—

Carbon	52·5
Hydrogen	8·0
Nitrogen	15·2
Sulphur	1·0
Phosphorus (?)	·6

ICICANE. [RESINS.]

ICONOGRAPHY (from εικων and γραφη), a description of images and their attributes. The term iconography applies generally to descriptions of the figures represented in ancient sculpture and painting, but it is frequently restricted to descriptions of the images which are found in monuments of mediæval art. In this sense iconography, or, as it is more accurately designated, Christian iconography, explains and illustrates, by means of written descriptions and pictorial representations, the images, whether historical, legendary, allegorical, or symbolical, of the three persons of the Trinity, the Virgin Mary, saints, angels, demons, animals, and natural objects, which are found represented in the churches, church furniture, carvings, pictures, stained-glass windows, funeral monuments, illuminated manuscripts, &c., from the earliest period of Christian art downwards to the 16th century. Works like E. Q. Visconti's 'L'Iconographie ancienne; ou recueil des portraits authentiques des empereurs, rois et hommes illustres de l'antiquite,' 3 vols. folio, Par. 1808–26; Montfaucon's 'L'Antiquité Expliquée et Representée en Figures,' and Müller's 'Denkmäler der Alten Kunst,' may be quoted as illustrations of the iconography of Greek and Roman art; whilst as examples of Christian iconography we may cite M. Didron's 'Iconographie Chretienne' (vol. i., 4to., 1843), which forms a volume of the 'Collections inédits sur l'Histoire de France,' and of which an English translation has appeared in Bohn's 'Illustrated Library;' the iconographic portion of De Caumont's 'Cours d'Antiquités Monumentales,' Guenebault's 'Dictionnaire Iconographique,' and perhaps Mrs. Jameson's more popular volumes on 'Legendary and Sacred Art.'

The term has also been applied to representations of objects in the animal and vegetable kingdom in a manner which will be best explained by the title of the work of M. Guérin Méneville, 'L'Iconographie du Règne Animal de Cuvier; ou, représentation d'apres nature de l'une des espèces les plus remarkable et souvent non encore figurées, de chaque genre d'animaux. Avec un texte descriptif,' 3 vols. 8vo, Paris, 1829–44.

ICONOLOGY (from εικων and λογος) the explanation of symbols, types and emblems, and of allegorical figures with their attributes. Of this kind are the 'Iconologie par figures; ou Traité complet des Allegories, Emblèmes, &c.,' of M M. Gravelot [H. F. Bourguignon]. and Cochin, 4 vols. 8vo., Paris, 1796; the 'Iconologie historique,' of M. C. Delafosse, 2 vols. folio, Paris, 1768; and the 'Iconologia,' of F. Pistrucci, Milan 1819-21, of which an English translation, in one vol. folio, was published in 1824 under the title of 'Iconology; or the Art of representing by allegorical figures the various abstract conceptions of the mind.' The term is not much used now.

ICOSAHEDRON. [SOLIDS, REGULAR.]

ICTERUS. [JAUNDICE.]

IDEA (ἰδέα, from the root ἰδ, to see), in its widest and now generally received acceptation, is employed to indicate every representation of outward objects through the senses, and whatever is the immediate object of thought. Like many other terms of mental philosophy, it is derived from the most eminent of the senses, that of vision. In the Platonic philosophy, the word idea possessed a higher import, and signified, primarily, the archetypes of all created things as they subsist in the divine intellect; and, secondarily, the conceptions of the human understanding, by means of which the essence of a thing is conceived. According to another, though a more questionable definition, the Platonic ideas denoted certain absolute qualities, which are regarded as real because they are capable of becoming objects of true knowledge. Plato's own definition is very extensive: "an idea may be attributed to whatever, as a plurality, may be indicated by the same name" (εἶδος γάρ πού τι ἕκαστον εἰώθαμεν τίθεσθαι περὶ ἕκαστα τὰ πολλά, οἷς ταῦτὸν ὄνομα ἐπιφερομεν. 'De Rep.' x. 596 a). For in Plato's loose phraseology the terms εἶδος and ἰδέα are employed indifferently in the same sense. This being remembered, there is little objection to Plutarch's historical account of these ideas, which we here give in the English of Holland. "Idea is a bodiless substance, which of itself has no subsistence, but giveth form and figure to shapeless matters, and becometh the cause that bringeth them into show and evidence. Socrates and Plato supposed that these be substances separate and distinct from matter, howbeit subsisting in the thoughts and imaginations of God, that is to say, of mind and understanding. Aristotle admitteth verily these forms and ideas, howbeit not separate from matter, as being patterns of all that God hath made. The Stoics, such at least as were of the school of Zeno, have delivered that our thoughts and conceits are the ideas." (Plutarch, ch. x., fol. 666; 'Opinions of Philosophers.')

Those ideas by means of which perception is obtained were commonly supposed to be really images or resemblances of external objects. By the Peripatetics however they were held to be inmaterial, while Epicurus and his followers made them to partake of the matter as well as of the form of their originals (tenui rerum simulacra). See Cic. 'ad Att Ep.,' ii. 3.) For the term idea the schoolmen employed the word *species*, by which, Cicero tells us, it was usually rendered in Latin ('Top.' 7), although he himself proposed "*form*," which has been in later times adopted by Kant and his followers to designate that constant element in the perception of outward objects which is independent of matter, and which the mind presents to itself in accordance with its own laws. These species the schoolmen divided into sensible and intelligible, of which we shall here extract Hobbes's clear and succinct account. "The philosophy schools teach that for the cause of vision the thing seen sendeth forth on every side a visible species, (in English) a visible show, apparition, or aspect, or a being seen, the receiving of which into the eye is seeing. . . . . Nay for the cause of understanding also the thing understood sendeth forth an *intelligible* species, that is, an intelligible being seen, which coming into the understanding makes it understood." ('Of Man,' part i., c. 1.)

The term idea was again introduced into philosophy by Des Cartes, with whom and his followers it is nearly synonymous with the species of the schoolmen. According to Locke, "Ideas are whatever is the object of the understanding, whatever a man thinks, or whatever it is the mind can be employed about thinking." (Letter to the Bishop of Worcester, 'Works,' vol. iv.) In this large sense the word is generally employed by English and French writers, and also by the Germans before the time of Kant, for the father of the critical philosophy ascribes to idea a higher but limited signification. By idea Kant eminently designated every conception formed by the reason (as distinct from the understanding), and raised above all sensuous perception. These *ideas* he subdivides into, 1st, empirical, which have an element drawn from experience, for instance, organisation, a state, a church; and 2nd, pure, which are totally free from all that is sensible or empirical, such as liberty, immortality, holiness, felicity, deity. Another division of the Kantian ideas is into theoretical and practical, according to a similar division of the reason itself. Thus the idea of truth is a theoretical idea, that of morality a practical idea.

For an account of the various theories, and his opinions of them, no better work can be named than the 'Lectures on Metaphysics' by the late Sir William Hamilton, published under the editorial care of the Rev. H. L. Mansel and J. Veitch, 1859, &c. There is valuable matter also in Sir William Hamilton's editions of the works of Dr. Thos. Reid, and of Dugald Stewart.

IDEAL has two uses, philosophical and critical. In the former it signifies, first, whatever belongs or relates to ideas generally. It is in this sense that the word is employed in the phrase "Ideal theory," in the controversy between Reid and Priestley. According to this theory, the understanding does not perceive external objects themselves by means of the sensuous organs, but the organs of sight and touch transmit to the mind certain ideas or images of sensible objects, which it perceives within itself. Locke, who received the term idea from Des Cartes, seems unconsciously to have adopted, with the use of the word, the scholastic doctrine which it involved. For he expressly declares that our ideas of the primary qualities of bodies are resemblances of them, but that those produced by secondary qualities are no resemblances at all. From this explanation of the means of perception, Locke has, on the one hand, been represented as the origin of modern idealism; while on the other, in consequence of the superior value which he evidently gives to the testimony of sensation, his authority has been claimed by the opposite school of ideology, as founded by the disciples of his French commentator Condillac. The second sense of the word is more limited, being confined to a peculiar class of ideas created by and solely subsisting in the imagination. Connected with this especial signification is its usage in the science of criticism, or æsthetics. Here ideal signifies a something which, although not existing in the reality of sensible things, subsists actually in thought—the joint creation of the reason and the imagination, the archetype and pattern of supreme and perfect beauty. Although unreal in nature, this ideal is not unnatural; it is the absolute sum and unity of those scattered beauties which nature, with a lavish but impartial hand, has diffused among her myriad phenomena. [ÆSTHETICS; BEAUTY.]

IDEALISM, the designation of many and different systems of philosophy, which only agree in the common principle from which they originate. This principle is the opposition of the ideal and the real, that is, of ideas and things—the contrariety of mind and body, or of spirit and matter.

1. As the essence of the mental lies in free activity and vital motion, as opposed to the invariable mechanism and inertness of the corporeal, the name of Idealism is rightly applied to those systems of physiology which make the primal substance and original of all things to be certain forces invisibly working throughout the universe. To the idealists of this class belong the dynamical philosophers of the Ionian school, Thales. Anaximenes, Diogenes of Apollonia, and Heraclitus.

The fundamental position of their several doctrines was the assumption of a living energy which as it developes itself undergoes continuous alteration both of form and quality—a transmutation which is the cause of all generation in nature. For water, the primary substance of Thales, was not the simple element, but water pregnant with vitality; the infinite air of Anaximenes was an animated and animating energy; and the intellectual primary of Diogenes was not merely the atmospheric air, but a warm and perfect breath of life which pervades and ensouls the universe. While however in these philosophers the philosophical idea is more or less mixed up with divers sensible conceptions, Heraclitus seems clearly conscious of speaking figuratively of the primary substance. With him a universal and absolute life is the cause of all phenomena, which indeed is most strongly and openly manifested in the vitality of fire and the rational soul, which is like to fire, while in other phenomena it is inherent, although not so obvious and immediately cognisable. In this class of idealists among moderns we must reckon Boscovich and Leibnitz. The former explained matter to be a system of forces; while, according to the latter, all beings are of the same nature. Activity and simplicity are the essential characters of all, and are so many forces or causes which he terms *monads*. All these monads possess the faculty of *perception*, or of reflecting within themselves, as in a mirror, the universe. These images however of perception cannot become the objects of knowledge, unless in these monads, which possess also what Leibnitz calls apperception, by which they are enabled to distinguish and see in themselves these images. It is therefore this faculty of apperception which constitutes the difference between the so-called material and spiritual; and as the faculty itself admits of different degrees, there are corresponding orders of intelligences. Lastly, we must include in this class, if anywhere among the idealists, the system of Spinoza, who asserts the identity of matter and spirit, making them to be but different aspects of one and the same substance; and Schelling, whose philosophy may be regarded as the complement of that of the Jewish philosopher.

2. Another species of idealism considers the real as simply ideal, and assumes that our representations of a material world correspond to nothing actually existing, but that by contemplating these as objective, we transmute the merely ideal into the real. The fundamental axiom of this idealism is the priority of the ideal and the subsequence of the real ('ideale prius, reale posterius'). Accordingly, the real only exists so far as it is necessarily conceived by us, so that the external world is purely a creation of our conceptions, or, in other words, the real is a product of the ideal. To this class is referred the Platonic attempt to account for the existence of the sensible world by his *ideas* alone, without recourse to any other nature alien and foreign to them. By some, even the Aristotelian philosophy is designated as ideal in this sense, at least so far as regards its fundamental principle. This they make to be the assumption of a universal mundane intelligence (νοῦς), which, as the principle of all things is a force (ἐντελέχεια), self-active, all-perfect, and absolutely free. The manifold manifestations of this entelechy are forms before and beside which matter exists only potentially, while the forms are determined and distinguished by privation (εἶδος, ὕλη, στέρησις). But the most perfect of idealists in this class is Fichte, who derives not merely the form, but also the matter, of the conception of external things out of the mind itself, or, in his terminology, out of the *ego* (Ich).

3. A third system of idealism proceeds to the absolute denial of all material existences. This species of idealism was impossible among the ancients, who did not oppose mind so sharply to matter as to deny the possibility of their interaction, but tacitly supposed their similarity, opposing only corporeity, as composite, to incorporeity, as simple. Of this idealism Bishop Berkeley is the author, although Des Cartes gave occasion to it by his position, that nothing extended can enter the unextended soul. Arthur Collier maintained the same theory, by a different line of argument, and Locke afforded, by his doctrine of ideas, the arguments for its support. The system of Berkeley is briefly this: matter does not exist independently of our sensations, but conceptions of a material world are produced by the operation of the deity upon our understanding, and the material world exists only in the divine intellect, who awakes in us certain sensuous conceptions in a definite order, which order is what we call the course of nature.

4. The last species of idealism is more philosophical, and, without denying or asserting the existence of a material world, is content with confessing an ignorance of its nature. It pretends not to a knowledge of things themselves, but is content with employing the ideas which the mind forms, according to the laws of its own nature, upon the occasion of the excitement of its sensuous organs, without determining whether these ideas correspond or not to the exciting cause or causes, whatever they may be. To this class belong Malebranche and Kant. According to the former, mind and matter cannot act upon each other, and the sensations of the mind are so many occasional causes operating by a constant miracle of divine agency. (*Deus ex Machinâ*) According to the latter, all that we know of outward objects is that they furnish the material part of our conceptions, to which the mind furnishes the form agreeably to its original and connatural laws; while of things themselves, which he calls phenomena, we absolutely know nothing, but note only the modes under which they appear to us.

Idealism in fact forms the antithesis to realism, which involves materialism. Sir William Hamilton in his 'Lectures on Metaphysics' says—"a philosophical system is often prevented from falling into absolute idealism or absolute materialism, and held in a kind of oscillating equilibrium, not in consequence of being based on the fact of consciousness, but from the circumstance that its materialistic tendency in one opinion happens to be counteracted by its idealistic tendency in another; two opposite errors in short, co-operating to the same result as one truth. On this ground is to be explained why the philosophy of Locke and Condillac did not more easily slide into materialism." (Lecture xvi.) He also observes ('Discussions on Philosophy,' &c.) that "mankind in general believe that an external world exists, only because they believe that they immediately know it as existent." But of course if this *knowledge* be disallowed, if the perception be only existent in the mind, the conclusion would be unfounded.

IDENTITY designates in philosophical language the sameness of a substance under every possible variety of circumstances. In this sense it is employed in the phrase *personal identity*, where it signifies the invariable sameness of the thinking subject, or *ego*. In a secondary sense it denotes a merely relative identity, which may also be called logical or abstract. Thus, in logic, whatever things are subjects of the same attribute or collection of attributes are considered the same; for example, dog and lion are the same relatively to the common notion Quadruped, under which they are both contained. Again, in physics, a tree may be asserted to be the same in relation to all the rights of property, notwithstanding the physical change it undergoes from the constant segregation of old and aggregation of new particles. Lastly, it is only in this logical use of the term that we can be said in memory to be conscious of the identity of the reproduced and the original idea, for if they were absolutely identical it would be impossible to distinguish between the first appearance and the recurrence of an idea. (Ancillon.)

According to Butler it is impossible to define the idea of personal identity, but it is easily ascertained; for a comparison of one's self in any two moments of our existence suggests immediately the idea, and at the same time the identity of ourselves. ('Essay on Personal Identity.') Reid's view is nearly similar: "I cannot remember a thing that happened a year ago, without a conviction, as strong as memory can give, that the same identical person who now remembers that event did then exist." ('Essays,' ch. vii.) To the objection that consciousness, being successive, cannot be the same in any two moments, and that therefore, as consciousness constitutes personality, there cannot be any identity of person, Butler answers, that consciousness presupposes and consequently cannot constitute personal identity, and that the object perceived may be the same notwithstanding that the perceptions by which it is discerned are distinct and different. Locke's opinion on this subject appears to have been undecided. "The identity of the same man consists," he says, "in nothing but a participation of the same life, by constantly fleeting particles of matter in succession vitally united to the same organised body." But personal identity he defines to be the sameness of a rational being. (Locke, 'On the Understanding,' p. 2, c. xxviii., s. 6.)

With respect to identical propositions, it is rightly observed "that the greatest assurance and most certain knowledge we can have of any thing is of such propositions as in the schools are called identical." (Sir Kenelm Digby, 'On Man's Soul,' c. ii., p. 28.) For in deductive reasoning the proposition and assumption which make the major and minor premises of the regular syllogism are only logical transmutations of the identical position in physics, that the whole is equal to its parts. Things which are logically identical may be conceived to be so many parts constituting a whole (genus); and the principle, "de omni et nullo" is rightly expanded thus: whatever belongs, or not, to a constituted whole, does or does not belong to all its constituent parts. In the same manner all mathematical propositions are identical; and Aristotle rightly teaches that in these equality is identity (ἐν τούτοις ἡ ἰσότης ἑνότης, 'Metap.' x., c. 3): the ultimate form to which all equations are reduced being $a=a$. It is the want of this identity that constitutes the difference between demonstrative and probable reasoning, although this difference is rather one of degree than of kind; for the inferior certainty in the latter arises from the difficulty of determining, in matters which fall within its domain, what really are all the constituent parts in any whole, or general term; whereas in the former every whole consists of certain determinate and limited parts, so that the procedure to a knowledge of the parts is easy.

By the system of absolute identity is meant the doctrine which teaches the oneness of the subject and object (spirit and matter) as merely different aspects of one substance. This is maintained by Schelling, Hegel, and Cousin, who hold that mind and matter are but "phenomenal modifications of the same common substance," and who reject the conclusion that "the evidence of consciousness to their antithesis is existence."

IDEOLOGY (the science of ideas or mind) is the term by which the later disciples of Condillac, under the Directory and the Empire, have designated the history and evolution of human ideas considered as so many successive modes of certain original or transformed sensations. Proceeding from this exclusive and partial view, nothing perhaps can equal the logical simplicity of the writings of this school, the subtlety of its abstraction, the boldness of its generalisations, or its analytical dexterity in reducing an idea to its simplest expression. Its metaphysical aspect is ably exhibited in the 'Idéologie' of Destutt de Tracy. With him we should also class Main de Biram and Laromiguière, but for the many traces in their writings of dissent from the system, so that they may more properly be considered as forming the transition to that form of mental philosophy in France developed by Royer Collard and his disciples, Jouffroy, and Cousin.

IDES. [KALENDAR.]

IDIOT. [LUNACY.]

IDRIALIN ($C_{30}H_{28}O_2$?), a hydrocarbon found in the mines of Idria. It colours sulphuric acid intensely blue. It is probably identical with *succisteren*, a substance obtained from amber, and which has the same property of colouring oil of vitriol intensely blue.

IDRYL (C_6H_2). A peculiar fusible and volatile hydrocarbon, obtained by the destructive distillation of a kind of coal found in the quicksilver mines of Idria.

IDYLL (Greek, εἰδύλλιον; Lat. *Idy'llium* or *Edy'llium*) is a poem "descriptive chiefly of the processes and appearances of external nature;

or of characters, manners, and sentiments; or of these in conjunction with the appearances of nature. The epitaph, the inscription, the sonnet, and most of the epistles of poets writing in their own persons, belong to this class." ('Preface' to Wordsworth's 'Poems.') In Greek the bucolic poems of Theocritus are called idylls; and all bucolic poetry [Bucolics] may be included under this name; though the ancients did not, any more than ourselves, confine the name to bucolic poetry, as may be seen by referring to the 'Idylls' of Ausonius. In English poetry, the 'Seasons' of Thomson, Shenstone's 'Schoolmistress,' the 'Cotter's Saturday Night' of Burns, the 'Allegro' and 'Penseroso' of Milton, Beattie's 'Minstrel,' Goldsmith's 'Deserted Village,' &c. belong to this class; Mr. Tennyson in his 'Idylls of the King,' has applied the term Idyll in a still more extended sense.

IGASURIC ACID. [Nux Vomica, Alkaloids of.]

IGASURINE. [Nux Vomica, *Alkaloids of.*]

IGNIS FA'TUUS, a meteor resembling a flame, said to float in the atmosphere at a few feet above the surface of the ground. It is stated to be generally observed by night, either stationary or in motion, over marshes or burial grounds; but in the 'Philosophical Transactions,' for 1694, there is an account of some ricks of hay being burnt at Dolgelly, in the preceding year, by a vapour like a weak blue flame which came from the sea. Derham ('Phil. Trans.' 1729) relates that he observed about a decayed thistle a flame in motion, which receded from him as he advanced towards it; and Beccaria states that be saw one which seemed fixed to a spot about two feet above some stones near a river: this philosopher observes that such meteors are most usually witnessed during a fall of rain or snow; he adds that they often appear on clayey soils, and that they have been seen to give out sparks. Trebra ('Deutscher Merkur,' Oct. 1783) mentions that he saw at Zellerfeld a meteor which at first approached him and afterwards receded from him to a distance of 500 paces; he adds that it then disappeared, and at the end of half an hour it again became visible.

Occasionally such meteors have been observed to follow or advance towards a spectator; but in general they appear to recede on being approached, and it has happened that from their resemblance to the flame of a distant lamp, they have led the unwary traveller into dangerous swamps. Little confidence can be placed in the descriptions given of them, as few persons have been able to examine them with due attention; and commonly they have been observed under the influence of an ill-regulated imagination rather than a philosophical spirit.

A plausible hypothesis which has been proposed in order to account for this phenomenon is that a phosphuretted or a carburetted hydrogen gas, produced by the decomposition of animal or vegetable substances, rises from the ground or from stagnant water, either small in quantity and occupying a single spot, or in great abundance and then becoming a train or a horizontal column of vapour of variable dimensions: such gas may take fire by electricity or spontaneously, at a spot where the atmosphere is particularly free from moisture; and the flame communicating itself successively to other parts of a line or column, the latter being in a state of undulation from the agitations of the atmosphere, will give rise to the appearance of a motion from place to place. The brightness of the meteor will change with the varying quantity or purity of the gas; and its temporary disappearance may be caused by the quantity being in some places too small to render the flame visible. Phosphuretted hydrogen would inflame spontaneously on coming into contact with atmospheric air, but no hydrocarbon, it must be objected, is spontaneously inflammable. There is a great dearth of satisfactory observations on moving lights seen in nature, and the entire subject is at present in obscurity. Electrical excitation, true phosphorescence, spontaneous inflammation, combustion otherwise occasioned, may all produce such lights, but whether such causes are really so operative, and whether their effects have been described as *ignes fatui*, remains to be proved.

IGNITION; INCANDESCENCE. These terms refer to that property of bodies, by which they give out light, when raised to certain high temperatures, the quantity of light increasing with the temperature within certain limits. At first it is of a dingy red, or *worm-red* as it is sometimes called; then bright red, indicating what is called a *cherry-red* heat; at a higher temperature we have an *orange* or yellow tint, and lastly a *white heat*, when the light is painful to the eye. Sir Humphry Davy's experiments placed the degree of incipient luminosity in the dark at about 810°, but a dull red visible in daylight is probably equal to 1000°, a full red heat 1200°, an orange heat 1700°, a white heat 3000°, and the high white heat of a good wind furnace (according to Daniell) about 3300°. These remarks apply to bodies which can be raised to these high temperatures without changing their state. Most bodies are dissipated or destroyed before they attain the temperature necessary for ignition, and if heated in the air they inflame and undergo combustion.

I'LEUS, or ILIAC PASSION, is a name given to a severe form of intestinal disease, characterised by violent griping pain around the the umbilicus, spasm and retraction of the muscles of the abdomen, obstinate costiveness, and vomiting. These symptoms are however common to several very different conditions of the bowels; they occur in severe cases of colic [Colic] from spasm, or as some suppose, paralysis of a portion of the intestinal canal, but more commonly they are the result of some mechanical obstruction of the canal, as by intussusception, internal hernia, unnatural adhesions between adjacent folds of intestine, &c. [Hernia.] The treatment must therefore vary according as one or other of these conditions is presumed to exist. In the first class of cases the remedies adapted for colic, combined with active purgatives, should be employed, while in those attended with mechanical obstruction, in which there is always great tendency to inflammation of the intestines, bleeding should be had recourse to, together with purgatives combined with opium, stimulant enemata, and anodynes.

ILICIN, a neutral crystalline vegetable principle, obtained by precipitating a decoction of holly leaves (*Ilex aquifolium*) by di-acetate of lead, evaporating the filtered liquor, and treating the residue with boiling absolute alcohol; by spontaneous evaporation there are produced transparent brownish-yellow crystals, which are bitter, and readily soluble in water, but not in ether. The solution is not precipitated by metallic oxides. This substance has been recommended as a powerful remedy in dropsy and intermittents.

ILLEGAL CONTRACT. [Agreement; Public Policy.]

ILLUMINATING. [Palæography.]

ILMENIC ACID. [Ilmenium.]

ILMENIUM (Il). A mineral first called *Urano-tantalite* has long been known in the neighbourhood of the Ilmen Mountains, in Siberia; but from the fact that it contains no tantalic acid, M. Rose has altered its name to *Samarskite*, it being principally found at Samarski. M. Hermann, however, gives to this mineral the name *Yttro-ilmenite*, asserting that it contains the oxide of a new metal analagous to tantalum, and to which he has given the name *Ilmenium*.

Ilmenic Acid (IlO_2), the binoxide of ilmenium, is the form, according to Hermann, in which the new metal exists in yttro-ilmenite. M. Rose, however, insists that the so-called ilmenic acid is only niobic acid, with a small quantity of tungstic acid, and that a mixture of these latter acids exhibits all the re-actions assigned by M. Hermann to ilmenic acid.

The existence of ilmenium, therefore, as a separate and distinct metal, is not at present satisfactorily established.

IMABENZILE ($C_{28}H_{11}NO_2$). An ammoniacal derivative of benzile. [Benzoic Group, *Benzile.*]

IMAGES, ELECTRIC, OPTICAL, THERMOGRAPHIC, &c. [Breath-figures; Electrical Images; Lens; Light.]

IMAGINARY. [Negative and Impossible Quantities.]

IMAGINATION denotes in its widest sense that faculty of the mind by which it produces at will thoughts or ideas as materials for every other mode of the mental activity. It is often employed in a narrow acceptation as synonymous with fancy, which properly is only a particular species of imagination combined with judgment. Still narrower is the domain of this faculty according to the definition of Dr. Reid, who confines it to a lively conception of the objects of sight, and makes the imagination to differ from conception only as a part from the whole. And similarly Addison teaches that "the pleasures of imagination are such as arise from visible objects, since it is the sense of sight that furnishes the imagination with its ideas." In its widest signification however imagination is coextensive with invention, furnishing the writer with whatever is most happy and appropriate in language, or vivid and forcible in thought. In the same manner it is the imagination that suggests to the scientific inquirer those bold conjectures of analogy or difference which lay open the secrets of nature and multiply its usefulness to man. Indeed, to adopt the language of Dugald Stewart, "All the objects of human knowledge supply materials for her forming hand; diversifying infinitely the work she produces, while the mode of her operation remains essentially uniform."

It is in this illimitable activity that imagination differs from conception, which also is a reproductive faculty, but apparently a mere passive potentiality to bring forth certain given and particular ideas; while the former, when once awakened by the presentation of a single thought, produces out of its storehouse of ideas all the manifold variations of similar and dissimilar. In this procedure, while it is bound indeed by the general laws of association, it is yet free to choose the principle of its combinations. Accordingly every age and every sex, every form of government and of religion, is said to have its special succession; and what is called a knowledge of men consists in nothing else than a knowledge of the train in which their ideas respectively succeed to each other.

A disordered imagination exhibits itself under various forms or characters; as the fantastic, the fanatic, and the enthusiastic.

On the particular character of the imagination depends much of the happiness or misery of the individual. Acting upon human hopes and fears, it assumes the name of sensibility, and by the bright or sombre images with which it fills the distant prospect of life it affords a double relish to every enjoyment or gives a keener edge to sorrow and misfortune.

IMASARATIC ACID. [Indigo.]

IMASATIN. [Indigo.]

IMBECILITY. [Insanity.]

IMESATIN. [Indigo.]

IMIDES. [Organic Bases.]

IMITATIONS, in Music. [Fugue.]

IMMATERIALISM. [Materialism; Berkeley, in Biog. Div.]

IMMORTALITY. [Materialism.]

IMPACT. [Collision, Impact, or Percussion of Bodies.]

IMPEACHMENT. [Parliament.]

IMPENETRABILITY, a name given to the property of matter, the existence of which is suggested when we see that any attempt to place one solid body in the part of space occupied by another is either resisted by the latter, or its success preceded by the removal of the latter. It is then but another name for the cause of that resistance, which we know by the sense of touch, and which is necessary to every idea which we form of matter.

The impenetrability of matter can only be taken in conjunction with the hypothesis of its porosity. Otherwise, it might be successfully disputed. Salt may be dissolved in water without increasing the bulk of the fluid; the (impenetrable?) matter is then penetrated; or else the matter of the fluid has interstices. But if any attempt be made to press the fluid into a smaller space, the impenetrability of the water will appear by its resistance to the pressing substance.

Are we not then making a purely gratuitous introduction of words to supply explanations of phenomena? When matter resists, we have recourse to impenetrability, which is merely saying, so soon as we find resistance, that matter has a power of resisting. But when we ascertain that different portions of matter can be made to fill the same space, whether by solution, pressure, or otherwise, we then appeal to a porosity which we cannot make visible, and presume that matter has empty spaces in which other matter may be placed. This is very much like nature's horror of a vacuum, and other explanations of the same kind.

The answer to this difficulty, and others of a similar kind which occur in attempting to define simple mechanical terms, is that the beginner must not receive them as explanations or as doctrines, but simply as statements of observed phenomena, or at best as terms which imply that explanation is wanted, and serve, till further explanation, to enable us to recal the phenomena themselves and the universality of their existence. Subsequent study and experiment must ascertain the character of this impenetrability, that is to say, the laws of the resistance from which it derives its name. The term is useful to remind us that there is a something which shows itself in all matter; but neither its etymology nor any common notions attached to it must be allowed to dictate any conclusion as to the nature, mode of action, or consequences of that something.

A closer inquiry into the action of matter upon matter shows us that the fundamental notion upon which the above-mentioned something received the name of impenetrability is incorrect. That notion evidently was, that when, for instance, one ball is rolled towards another, the rolling ball absolutely touches the stationary one before it causes motion. There are many circumstances from which it can be inferred, with the highest degree of probability, that such contact is only apparent, and not real. It must be concluded that when the two balls come within a certain small distance of one another, repulsive forces, of the cause and mode of action of which we know nothing, begin to be excited between those particles of the balls which are nearly in contact. It is not our intention in this article to go further into the preceding subject than the mere mention of what are called *molecular* attractions and repulsions, and this merely to point out that the action of matter upon matter must be admitted to commence before the instant at which their surfaces come into contact. [Attraction; Inertia.]

IMPERATOR. [Emperor.]

IMPERATORIN, *Peucedanin*, ($C_{24}H_{12}O_6$), a neutral crystalline vegetable product, procured from the root of the *Imperatoria Ostruthium*: it is obtained by exhausting the root with ether, distilling the greater part of it, and submitting the remainder to spontaneous evaporation, by which the imperatorin is obtained crystallised in prisms, which are colourless, transparent, inodorous, styptic, and acrid; they do not alter vegetable colours; they melt when heated to 167°, and concrete into a radiated mass, the density of which is 1·192. At a high temperature imperatorin is decomposed, diffusing an acrid vapour. It is insoluble in water, but soluble in alcohol, ether, olive oil, and oil of turpentine; when dissolved in a solution of potash, it is precipitated from it by acids, unchanged. Sulphuric acid dissolves imperatorin, and assumes a brownish red colour; in nitric acid it dissolves with a yellow tint: these solutions are both decomposed by water. Iodine forms with it a brownish red compound, which yields iodine when heated.

IMPERMEABILITY, that property by which certain substances resist the passage through their mass of other substances: such, for example, as glass, the pores of which are so small that under no pressure hitherto applied have fluids been driven through them; whereas gold is permeable by water, as in the celebrated experiment of the Florentine Academicians. Some substances are impermeable in consequence of their repulsions to other bodies, such as oilskin or waterproof cloth, which is impermeable to water, in consequence of the repulsion existing between oil and water.

IMPETIGO is a term which has been employed by writers in many independent significations, and for various diseases, but is now confined to a disease of the skin, which Dr. Willan has defined to be "an eruption of yellow itching pustules, appearing in clusters and terminating in a yellow, thin, scaly crust." It is commonly known in this country as the humid or runing tetter, and occurs on all parts of the body, though most frequently on the extremities.

A variety of it is not unfrequently met with in grocers and those much engaged in handling sugar, and to this the term grocer's itch has been applied; but it differs from the itch, properly so called, in its non-contagiousness. [Skin, Diseases of.]

IMPETUS. [Momentum.]

IMPONDERABLE, a term applied to heat, light, and electricity, regarded as *fluids;* but as in modern science they are regarded rather as *forces*, the term has gone out of use.

IMPORTS AND EXPORTS. [Trade and Shipping.]

IMPOSSIBLE. [Negative and Impossible Quantities.]

IMPOST (*Imposta*, Italian), the horizontal mouldings which serve as a sort of cap or cornice to the piers of arches, and on which the archivolts, or curved mouldings and faciæ surrounding the arches themselves, rest. Like these latter the impost is made plainer or richer according to the order employed, or to the general character of the design. And when the archivolts of the arches are omitted, either the impost is omitted likewise, or a plain band is substituted for it. This is generally done in the rusticated basements beneath an order, the joints of the rustics sufficing for decoration, and giving the requisite architectural expression. Imposts, properly so called, are seldom found in pointed Gothic, except in the First Pointed style; but the point of junction between the curve of an arch and its support, however treated, is called the impost. Except in the case above alluded to, the impost is essential in Roman and Greco-Roman architecture. We have, however, a few recent instances in which imposts have been omitted, and the archivolt of the arch continued vertically down the edges of the piers. This was a favourite practice with Soane, both in his designs and many of his executed buildings; and it has been followed by other architects, but the effect is by no means happy.

IMPRESSMENT. [Seamen.]

IMPRISONMENT, FALSE. [False Imprisonment.]

IMPROPRIATIONS. [Benefice; Tithes.]

IMPROVEMENTS, PUBLIC. [Public Improvements.]

IMPROVVISATORI are extempore versifiers who can, without preparation, pronounce a certain quantity of verses upon any given subject. This practice is of frequent occurrence in Italy, and the facilities which the structure of the Italian language affords to versification and rhyme are of great assistance towards it. The improvvisatore delivers his verse, generally accompanied by a guitar, and with a sort of chaunting cadence; and he spins out hundreds, nay at times thousands of lines, with apparent ease: whole dramas have indeed been thus delivered. It must not be imagined however that this kind of extempore poetry is of the best kind; in reality very few of those compositions can stand the test of publication. Still they have the merit of the flow of language and the quick adaptation of accessory ideas and images to the main subject, which rivet the attention and excite the surprise of the listener.

Some improvvisatori have been men of real information and poetical genius, and their compositions are consequently superior. An Augustine friar of the name of Brother Philip, blind and living in the time of Sixtus V., is mentioned as having done wonders in this way. Gianni, of Genoa, a man of considerable poetical talent, was made improvvisatore to the court of the Emperor Napoleon I., with a handsome salary; and Sgricci of Florence became known throughout Europe by giving specimens of his art in the various capitals. Several ladies have distinguished themselves in the same art: they are styled improvvisatrici.

IMPULSE. When a body rolls down a gently-inclined plane we can see the gradual alterations of its velocity, and can readily admit that between the instants at which the body has two different velocities it takes in succession all intermediate velocities, or that the change of velocity is perfectly gradual. But when a body is violently struck, as in the case of a bat and a ball, we can see no gradations of velocity, but the ball appears to be at once altered from a state of rest into one of rapid motion, without having passed through any of the intermediate states. In this case it is said to have received an *impulse*, which word must be interpreted to mean any cause by virtue of which velocity is communicated suddenly and without gradations.

Though the term impulse may be of convenient application to cases of motion in which velocities are changed very rapidly, it must be remembered that the idea of absolutely instantaneous change of velocity is in no degree less absurd than that of a point which is in two different positions at the same instant of time. Impulse, then, must be considered as pressure which, beginning from nothing, increases so rapidly with the time as to produce large effects in a small fraction of a second. Some account of the manner in which impulses act is given in the article Pressure.

It is to be remembered that there is nothing absurd in the idea of any change in the state of a body, provided that a time, no matter how small, be allowed for it to take place in. A cannon-ball now at rest may, in the millionth part of a second, be imagined to have acquired a velocity such as it has when it issues from the mouth of the gun, provided only that a pressure be imagined sufficient to produce the effect. It is only the production of velocity in no time at all which must not be admitted; though it must be owned that the excessive smallness of the times in which some pressures produce a great effect makes us familiar with the notion of impulse, which further inquiry shows us to be a mechanical impossibility as long as the present laws of nature last.

INARCHING. [GRAFTING.]

INCANDESCENCE. The luminous glow of a solid or liquid body intensely ignited. [IGNITION.]

INCENDIARY. [ARSON; LAW, CRIMINAL.]

INCEST. During the Protectorate incest and adultery were made capital offences, but at the Restoration this law was not renewed. Incest in England is now punishable only by the ecclesiastical courts, according to the canon law, which determines what kind of sexual connection is incest. It may be committed either by married persons or persons unmarried. Adultery may be incest, and fornication may also be incest; the legal notion of incest being founded upon the degree of consanguinity or affinity between the parties.

The term is derived from the Roman Incestum, which is the same as Non Castum, "not pure," and in its most general sense signifies any offence against positive morality, or religion. Persons within certain degrees of consanguinity could not contract a marriage; if they did, or lived together as man and wife, such a connection was called incestuous (Incestae Nuptiae). The affecting to marry was not however necessary to constitute Incestum. It existed whenever there was sexual connection between a man and woman who were incapable of contracting marriage. If the parties were capable of contracting marriage, the connection would be Stuprum, which in its limited sense, corresponds to fornication.

The Romans do not appear to have had any direct legislation on this subject till the Imperial period, and the rules of law that were in force were founded upon positive morality and usage. The Lex Julia which was enacted in the time of Augustus treated of incest only indirectly, and so far as it concerned the object of that law, which was the punishment of adultery. In some cases the punishment was capital. (Dion. Cassius, lviii. c. 22; Tacitus, 'Annal.,' vi. 19.)

The subject of the Roman Incestum is treated copiously by Rein, 'Criminalrecht der Römer,' and with a reference to the numerous authorities.

INCH OF CANDLE. [AUCTION.]

INCIDENCE, ANGLE OF, a term used in catoptrics, radiant heat, &c., to express the angle between the direction in which a line strikes on a plane, and the perpendicular to that plane.

INCINERATION. An operation in organic chemistry, which has for its object the separation of inorganic from fixed organic matters. It consists in heating the organic substance to redness in a current of air (in a muffle for instance) until all the organic matter is consumed, the non-volatile inorganic matters are then left behind as an ash.

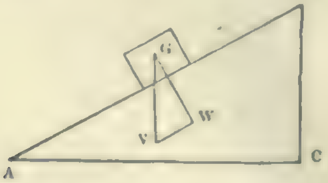
INCLINATION. [MAGNETISM.]

INCLINATION. The inclination of two lines is a phrase commonly used for the angle which they make with one another. Thus, two lines which make a very small angle are said to be at a very small inclination to each other. Looking at the etymology of the word, and its use in common language, it would seem proper to say that one line is without inclination to another when the two are perpendicular, and that the smaller the angle the greater the inclination. But custom has settled otherwise, and has, in fact, made the word inclination synonymous with angle; while the term angle of incidence holds the place which, according to etymology, belongs to angle of inclination.

INCLINED PLANE. Among the mechanical powers, as they are termed, meaning the contrivances by which pressure is advantageously applied, the inclined plane has held a place in practice in every country in which the arts have made any progress. But the introduction of this contrivance into the theory of mechanics dates from the time of STEVIN, to whose life in the BIOG. DIV. we refer for an account of the very remarkable addition which he made to the first principles of statics by means of the inclined plane.

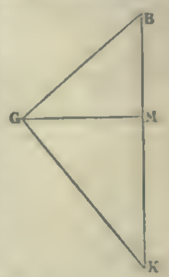
If a weight be placed upon a horizontal plane on which there is no friction, it is obvious that the weight will be entirely supported, and that any horizontal pressure, however small, will cause motion. If the same plane be made vertical instead of horizontal, the weight cannot be placed *upon* it, for if the heavy body were made to touch the plane and then left to itself, it would fall down the plane exactly in the same manner as it would fall if there were no plane; that is, supposing there to be no friction.

If the plane be made to assume an oblique or inclined position, the effect produced will be intermediate between those of the preceding cases. The weight will not rest, nor will it acquire velocity as rapidly as when it falls freely. The reaction of the plane will counterbalance a portion of the weight, as follows:—Let A B represent a section of the plane, and G a section of the weight. Let G V represent the magnitude and direction of the weight, and draw G W and W V perpendicular and parallel to A B. Then [COMPOSITION] the pressure G V is equivalent to the two pressures G W and W V, of which the former is destroyed by the resistance of the plane, and the latter only acts to propel the heavy body down the plane. Now V W is to V G as B C is to A B; that is, a weight placed upon an inclined plane is propelled down the plane by such a fraction of the whole pressure of the weight as the height of any section of the plane is of its length.



If then it were required to draw the heavy body G up the plane, any pressure exceeding V W would be sufficient for the purpose: and a pressure equal to V W, applied in the direction A B, would keep the weight at rest.

If a body which is placed at B on an inclined plane be allowed to fall to G, the velocity which it will then have, and the time of describing B G, are determined as follows:—Let B K be vertical, G M horizontal, and G K perpendicular to B G. Then the velocity at G is that which would be acquired by a body falling freely from B to M; and the time of describing B G would be that in which a body falls freely from B to K. From hence follows immediately the remarkable proposition that if any number of chords be drawn from the highest point of a vertical circle, and if these chords be the sections of as many inclined planes, the times of falling down any two of these chords are the same.



The preceding results are obtained by applying the method explained in the article FALL OF BODIES. Using the notation in that article, and supposing θ to be the angle by which the plane is inclined to the horizon, the accelerating force which urges the weight downwards is $g \sin\theta$. Consequently we have the following equations:—

$$v = g \sin\theta . t. \qquad s = \tfrac{1}{2} g \sin\theta . t^2. \qquad v^2 = 2g \sin\theta . s.$$

Here s is the length B G: and $s \sin\theta$ is B M.

The preceding results suppose friction not to exist: now let there be a friction, the proportion of which to the pressure is the fraction k. Then W representing the weight, the propelling pressure V W is W $\sin\theta$. But the pressure on the plane, or G W, is W $\cos\theta$; consequently k W $\cos\theta$ is the amount of pressure down the plane which friction will resist. If then k W $\cos\theta$ be greater than W $\sin\theta$, that is, if k be greater than $\tan\theta$, the weight will not move; if k be equal to $\tan\theta$, the weight will be just poised, and any pressure, however small, will cause motion; if k be less than $\tan\theta$, the weight will move downwards with an accelerating force $g (\sin\theta - k \cos\theta)$.

There are many remarkable properties connected with the motion or equilibrium of bodies on inclined planes; but the preceding are those which are most fundamental and most frequently required.

INCLOSURE. The term inclosure is applied to the inclosing and partitioning of lands in England and Wales, which are comprehended under the general name of Commons or Common Lands. A knowledge of the present condition of the lands comprehended under this term enables us to form a better estimate of the state of agriculture in England and its capabilities of improvement. We thus learn also what was the general condition of the lands in England before inclosures were made.

It is necessary to define the terms Commons, and Commonable and Intermixed Lands. Commons or Common Lands are lands in a state of nature or waste, of which individuals have not the severalty. Commonable Lands are those lands which during a part of the year are in severalty, that is, occupied severally by individuals as their own, to the exclusion for the time of other people.

There is great variety in these commonable lands; but they may be divided into three classes, exclusive of wood-lands: First, there is open arable and meadow land which is held and occupied by individuals severally until the crop has been got in. After the crop has been removed, that is, during the autumn and winter, it becomes commonable to persons who have severalty rights in it, and they turn on to it their cattle without any limit, or without stint, as it is termed. Thus there is a divided use in these open lands: individuals have the exclusive right to the enjoyment of one or more of these strips of open land for a part of the year; and during another part of the year all these individuals enjoy this open land in common. Second, there is open arable and meadow land that is held in severalty during one part of the year, like the first class; but after the crop is removed, it is commonable not only to parties who have severalty rights, but to other classes of individuals: these lands are generally called Lammas Lands.

These commonable rights may belong to a particular class, as a body of freemen, or to all landholders. There is great variety in these two classes as to the severalty holdings also. "There are many cases in which the severalty holding varies year by year. There are in these open lands what is called a pane of land, in which there may be 40 or 60 different lots. It is reported to be a remnant of an old military custom, when on a certain day the best man of the parish appeared to take possession of any lot that he thought fit; if his right was called in question, he had to fight for it, and the survivor took the first lot, and so they went on through the parish. It often happens that in these shifting severalties the occupier of lot one this year goes round the whole of the several lots in rotation; the owner of lot one this year has lot two the next, and so on. When these lands are arable lands, they do not change annually, but periodically, according to the rotation of the crops. Then there is the old lot meadow, in which the owners draw lots for the choice. There are a great variety of circumstances under which the severalty ownership of these lands shifts from time to time—but after the severalty ownership has ceased, and after the crop has been removed, they all become commonable."

This is one among many instances of the existence of ancient usages in England, which are the same or nearly the same as the usages of nations that we call barbarous. Tacitus ('Germania,' c. 26) says of the ancient German mode of agriculture: "The lands, in proportion to the number of cultivators, are occupied by all in turns, which presently they divide among themselves according to their rank (merit). The extensive plains offer facilities for division. They change the cultivated fields yearly; and there is still a superfluity of land." The meaning of Tacitus is not clear. The following passage in Cæsar's account of the Gauls (vi. 22) is more distinct: "They pay no attention to agriculture, nor has any man a fixed quantity of land and boundaries of property: but the magistrates annually assign to the clans and tribes who have come together, as much land as they please and where they please, and in the next year they compel them to move to another spot." Herodotus (ii. 168) says that each member of the military caste in Egypt had a certain portion of land assigned to him; but they enjoyed the lands in a rotation, and the same persons did not continue in the enjoyment of the same lands. Strabo (p. 315) mentions a custom amongst the Dalmatians of making a division of their lands every eight years.

"The third class is that of grazing lands, where the rights of parties are settled and defined, the ordinary stinted pasture. The commonable lands are subject to very great variety and peculiarity; for instance, in some of these lands the right of grazing sheep at all belongs to a man called a flock-master, and he has the power, during certain months of the year, of turning his own sheep exclusively on all the lands of the parish; or, according to particular circumstances, his right is limited and restricted to turning sheep upon a certain portion of it, with a view to giving parties an opportunity of putting in a wheat crop. In those parishes where there is a flock-master who has a right of depasturing his sheep during a certain portion of the year over all the land of the parish, it is clear that no one can sow any wheat without having made a bargain with him for shutting up his own particular fields, or some portion of them."

"There is a very large extent of woodland in this kingdom that is commonable, strange to say, where certain individuals have a right during the whole year, to turn on stock, the owner of the wood having no means of preserving his property except by shutting out other commoners' stock by custom for some two or three years after felling. There is that right, as also the old right of estover, which is a very great inconvenience, namely, where parties have the right of cutting house-bote, and plough-bote, and fire-bote, and so on in woods belonging, *quâ* wood, to another party. There is a great deal of land subject to that ruinous custom. There are many varieties of these commonable lands, but these are the most prominent and remarkable of them."

Under such a system as this, it is obvious that these common fields must be ill cultivated. The intermixed lands cannot be treated according to the improved rules of good husbandry. It is stated that the simple re-distribution of intermixed lands, now held in parcels so inconvenient in form and size as to be incapable of good husbandry, would in many instances raise the fee-simple value of the lands from 15*s.* or 17*s.* an acre to 30*s.*

It was the opinion of witnesses examined before the parliamentary committee of 1844, on Commons' Inclosure, that judicious inclosure would make a large portion of common lands much more productive. Open arable lands are so intermixed that effectual drainage is nearly impossible. One witness said: "I have had occasion to go over two small properties, about 150 acres each; one I found in 301 different pieces, and another in a little more than a hundred. I mention this to show how the lands are frequently intermixed; they are therefore farmed at much greater expense; and it is impossible to drain them on the present improved mode of drainage, inasmuch as other parties are occupying the furrow by which the water should pass off." In the Midland counties, where there are these open arable fields, the course is two crops and a fallow, and every third year the flocks run over the whole field. The same witness considered that a fourth of all the arable land was totally unproductive. In cases where common arable fields have been subdivided and allotted, "the great improvement is, that in the first place every man has his allotment, and he deals with it as he pleases; he drains it, and crops it upon a proper course of cropping; he puts it in seed and keeps sheep upon it; he grows turnips and clover, or whatever he thinks proper." The same witness was of opinion that the average improvement in the value of common fields which had been inclosed was not less than 25 per cent. Indeed, the evidence that was produced before the committee established to a degree beyond what otherwise would be credible, the immense inconvenience and loss which arise from the system of intermixed lands, and their being also subject to commonage.

As to Common Rights, that is, rights of pasture and so forth on commons or waste lands, they are described generally under COMMON, RIGHTS OF. As to the common pasture lands, they also require an improved management. It is stated that commons are generally overstocked, partly in consequence of persons turning out more stock than they have a right to do, and partly by persons putting their stock on the common who have no right. In consequence of commons being overstocked, they are profitable to nobody; and a rule for regulating the quantity of stock would therefore be beneficial to all persons who are entitled to this right of common. Violent disputes also frequently arise in consequence of the rights of parties to commonage not being well defined. It is the opinion of competent judges that very great advantage would result from stinting those parts of commons that are not worth inclosure; and that "it would be in many instances highly desirable to inclose portions of a common for the purpose of cultivation, and to allot such portions of it, whilst it would be impolitic to do more than stint other portions of it." A *stint* may be defined to be "the right of pasturage for one animal, or for a certain number of animals, according to age, size, and capability of eating." The commons in fact are not now stinted by the levant and couchant right, a right which cannot be brought into practical operation; and besides this there are many commons in gross. [COMMON, RIGHTS OF.]

In 1836 an act (6 & 7 Wm. IV. c. 115) was passed for facilitating the inclosure of open and arable fields in England and Wales. The preamble to the act is as follows:—"Whereas there are in many parishes, townships, and places in England and Wales, divers open and common arable, meadow, and pasture lands and fields, and the lands of the several proprietors of the same are frequently very much intermixed and dispersed, and it would tend to the improved cultivation and occupation of all the aforesaid lands, &c., and be otherwise advantageous to the proprietors thereof, and persons interested therein, if they were enabled by a general law to divide and inclose the same," &c. Inclosures have been made under the provisions of this act, but the powers which it gives are limited, for the "act applies solely to lands held in severalty during some proportion of the year, with this exception, that slips and balks intervening between the cultivated lands may be inclosed." The lands which cannot be inclosed under the provisions of this act are "the uncultivated lands, the lands in a state of nature, intervening between these cultivated lands, beyond those that are fairly to be considered as slips and balks." However, it was stated in evidence before the committee of the House of Commons in 1844, that a large extent of common and waste land had been illegally inclosed under the provisions of the act, and the persons who hold such lands have no legal title, and can only obtain one by lapse of time. The chief motive to this dealing with commons appears to have been, that they thus got the inclosure done cheaper than by applying to Parliament for a private act.

In 1844 a select committee of the House of Commons was appointed "to inquire into the expediency of facilitating the inclosure and improvement of commons and lands held in common, the exchange of lands and the division of intermixed lands, and into the best means of providing for the same, and to report their opinion to the House." The committee made their report in favour of a general inclosure act, after receiving a large amount of evidence from persons who were well acquainted with the subject. The extracts that have been given in this article are from the printed evidence that was taken before the select committee.

In pursuance of the recommendation of the committee, an Act of Parliament was passed in 1845 (8 & 9 Vict. c. 118), the object of which is thus stated in the preamble: "Whereas it is expedient to facilitate the inclosure and improvement of commons and other lands now subject to the rights of property which obstruct cultivation and the productive employment of labour, and to facilitate such exchanges of lands, and such divisions of lands intermixed or divided into inconvenient parcels, as may be beneficial to the respective owners; and it is also expedient to provide remedies for the defective or incomplete execution and for the non-execution of powers created by general and local acts of inclosure, and to authorise the renewal of such powers in certain cases," &c.

It is not within the scope of this article to attempt to give any account of the provisions contained in the 160 sections of this act; but a few provisions will be noticed that are important in an economical and political point of view.

The 11th section contains a comprehensive description of lands which may be inclosed under the act, in which the New Forest and the Forest of Dean were excepted, but even with these portions have been since inclosed, and the new plantations are fenced for a certain time. The 14th section provides that no lands situated within fifteen miles of the city of London, or within certain distances of other towns, which distances vary according to the population, shall be subject to be inclosed under the provisions of this act without the previous authority of parliament in each particular case. The 15th section provides against inclosing town greens or village greens, and contains other regulations as to them. The 30th section provides that an allotment for the purposes of exercise and recreation for the inhabitants of a neighbourhood may be required by the commissioners under the act, as one of the terms and conditions of an inclosure of such lands as are mentioned in § 30.

The 108th section makes regulations as to "the allotment which upon any inclosure under this act shall be made for the labouring poor," and (sect. 109) "the allotment wardens (appointed by sect. 108) shall from time to time let the allotments under their management in gardens not exceeding a quarter of an acre each, to such poor inhabitants of the parish for one year, or from year to year, at such rents payable at such times and on such terms and conditions not inconsistent with the provisions of this act, as they shall think fit." Section 112 provides for the application of the rents of allotments; the residue of which, if any, after the payments mentioned in this section have been defrayed, is to be paid to the overseers of the poor in aid of the poor-rates of the parish.

Sections (147, 148) provide for the exchanges of lands not subject to be included under this act, or subject to be inclosed, as to which no proceedings for an inclosure shall be pending, and for the division of intermixed lands under the same circumstances.

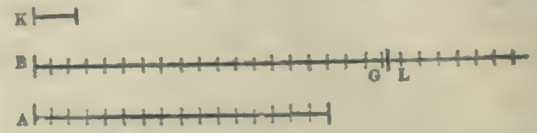
Under section 152 commissioners are empowered to remedy defects and omissions in awards under any local act of inclosure, or under the 6 & 7 Will. IV. c. 115; and under section 157, the commissioners may confirm awards or agreements made under the supposed authority of 6 & 7 Will. IV. c. 115, if the lands which have been illegally inclosed or apportioned or allotted, shall be within the definition of lands subject to be inclosed under this act. In accordance with this act two commissioners, with a secretary, were appointed, under whose management its provisions have been extensively carried into operation. The commissioners make yearly reports to parliament of the proceedings which have taken place, and one or more acts are passed every year confirming the inclosures submitted by the commissioners for approval. In their 13th annual report, presented in 1858, the commissioners state that the number of applications of all kinds for inclosures since the passing of the acts had been 2351, and that the whole acreage of inclosures confirmed prior to this report was 226,010 acres, while the acreage of inclosures in progress amounted to 262,418 acres.

The provisions of this act seem to be well adapted to remedy the evils that were stated in the evidence before the select committee; and there can be no doubt that agriculture has been greatly improved, the productiveness of the land increased, and employment given to labour by this judicious and important act of legislation.

INCOMMENSURABLE, INCOMMENSURABLES, THEORY OF. The application of arithmetic to any science of concrete magnitude supposes a certain magnitude to be taken as unity, and all other magnitudes to be expressed by the number of times or parts of times which they contain this unit. Such an application, therefore, made in the usual manner, requires the assumption of this proposition, that all magnitudes are either fractions or multiples, or compounded of fractions and multiples, of any magnitude that may be named. This proposition is not true; for instance, we shall presently prove that if the side of a square be called 1, no number or fraction whatsoever will exactly represent the diagonal. But we shall also prove that it may be made as nearly true as we please: for instance, that we may find a line as nearly equal to the diagonal as we please, which shall be a definite arithmetical fraction of the side. Quantities which are so related that when one is capable of being represented in terms of a certain unit the other is not, are called *incommensurables*. The reason is as follows: any two whole numbers or fractions of the same unit must have a common measure; thus, all whole numbers have the common measure 1; and any two fractions, $\frac{a}{b}$ and $\frac{p}{q}$ (a, b, p, and q being whole numbers), have the common measure $\frac{1}{bq}$, which is contained exactly aq times in the first, and bp times in the second. Conversely, any two magnitudes which have a common measure can be arithmetically represented by the same unit: for if A and B have the common measure M, and if this measure be contained 7 times in A and 10 times in B, then it is evident that by taking M as the unit, A is represented by 7 and B by 10. If, then, there be two magnitudes which cannot be represented by means of the same unit, they cannot have any common measure whatsoever, and are therefore *incommensurable*. It also follows from the preceding, that any two commensurable magnitudes must be to one another in the proportion of some one whole number to some other whole number.

To prove that there are such things as incommensurable magnitudes, we shall take the 117th (and last) proposition of the tenth book of Euclid, which demonstrates that the diagonal and the side of a square are incommensurable. Let D be the diagonal and S the side, and if they be not incommensurable let a and x be the whole numbers to which they are proportional; that is, let M be a common measure, and let D and S severally contain M, a and x times. Then the square on D will contain the square on M aa times; and the square on S will contain the square on M xx times. But the square on D is double of the square on S: therefore aa is twice xx. Now, let a and x have no whole common measure except unity, which may be supposed, for if they have a common measure, we may divide both by it, which will give two whole numbers in the same proportion, and so on until no common measure is left. Then, because a times a is double of x times x, a times a is an even number; whence a is an even number, for if a were odd, a times a would be odd. Therefore, x is not an even number, for if it were, a and x would have the common measure 2; whence x is an odd number. Let k be the half of a, which is a whole number, since a is even; whence $a = 2k$, and $aa = 4kk$, which is also $2xx$, and thence it follows that $xx = 2kk$. Therefore, xx is an even number, and x also; for if x were odd, xx would be odd: whence x is even. But it was just now proved to be odd; so that the same number is both odd and even, which is absurd. This contradiction follows whenever we suppose S and D to be in the proportion of any two whole numbers; consequently, S and D are not in the proportion of any two whole numbers, and therefore are incommensurable, for if they were commensurable they would be in the proportion of some two whole numbers.

We have next to prove that any two magnitudes whatsoever, being incommensurable, may be made commensurable by as small an alteration as we please in either.



Let A and B be two incommensurable magnitudes, and let K be a third magnitude of the same kind, which may be as small as you please, provided only that it be given and known. [INDEFINITE.] Now, some aliquot part of A must be less than K; if not the hundredth, try the thousandth; if not the thousandth, try the millionth, and so on. Whatever K may be, it is possible to divide A into equal parts, each of which shall be less than K. Let M be such an aliquot part of A, and having divided A into its parts, set off parts equal to M along B. Then A and B being incommensurable, B will not contain M, the measure of A, an exact number of times, but will lie between two multiples of M, say BG and BL. From this it is obvious that B does not differ from either BG or BL by so much as GL, and therefore not by so much as K. But BG and BL are both commensurable with A, since all three are multiples of M. Here, then, are BG and BL, the first a little less than B, and the second a little greater, neither differing from B by so much as K, but both commensurable with A. Thus it is also evident that two whole numbers may be found which shall be as nearly as we please in the same ratio as two given incommensurable quantities.

The difficulty thus inherent in the application of arithmetic to concrete magnitude is not met with in practice, because no case can arise in which it is necessary to retain a magnitude so closely that no alteration, however small, can be permitted. But in exact reasoning, where any error, however small, is to be avoided, it is obvious that the arithmetic of commensurable magnitudes, and the arithmetic (if there be such a thing) of incommensurable magnitudes, must not be confounded. The difficulty was overcome by Euclid, in the manner pointed out in the article PROPORTION, so completely and effectually that nothing has been added to his solution of it except unsuccessful attempts to evade it. Those who avoid the fifth book of Euclid generally substitute either the tacit assumption that all magnitudes are commensurable, which is not true, or some play upon words, which a person who feels the rigour of Euclid places on the same shelf with nature's horror of a vacuum and other explanations of the same kind. We could even point out a celebrated work on geometry which expressly rests on being able to make its errors too small to be perceived by the senses, and asks for no other reception of propositions which involve incommensurables.

The doctrine of incommensurable quantities was carried by Euclid to an extent which would excite as much admiration as any portion of his writings, if the tenth book were generally known and read as the production of a person unassisted by algebra. [IRRATIONAL QUANTITIES.]

INCOMPATIBLES, in Materia Medica, applied to those articles which are considered improper to be united in the same prescription. Strictly speaking, the term applies only to introducing into the same formula articles which exert a chemical action on each other, and so produce a result or compound of a useless or hurtful kind. Two or more articles may be introduced into a prescription, which by their combination neutralise the properties of each other. The resulting compound may be perfectly insoluble in the juices of the stomach, so as to be inert or hurtful by its insolubility. But this result is often sought on purpose to neutralise acrid or corrosive substances; such as when chalk or lime from a wall is given to a person who has swallowed oxalic acid. [ANTIDOTES.] But entire loss of power does not invariably result from combining substances which chemists deem incompatible; thus chalk and opium form a more powerful astringent than either singly given; and opium and acetate of lead in warm water form a fomentation of much use in erysipelas. But that utterly inert compounds often resulted from bringing together numerous ingredients is certain, as seen in the Polypharmacy of the ancients, of which the famous Mithridate is an instance. Even this has been surpassed in modern times, some prescriptions of Huxham containing above four hundred ingredients. On the opposite hand, excessive simplicity is perhaps too much aimed at in the present day. Dr. Paris' 'Pharmacologia' may be advantageously referred to; and Translation of the 'London Pharmacopœia,' by Richard Philips.

INCONCINNOUS INTERVALS, in Music, are sounds which agree with no scale, therefore are disagreeable to the ear, and never used in any kind of composition.

INCREMENT and DECREMENT. When two quantities are considered together, one of which is greater or less than the second, the latter is said to be the former with an increment or decrement. In the older English writings the calculus of differences is called the method of increments. This phraseology refers to the supposition of magnitudes being generated by continued increase or decrease as in the method of fluxions, so that two different magnitudes are spoken of as the same thing in different states, and of course at different times. Some difficulty to the beginner may be occasionally avoided by his stopping to interpret "let x become $x+h$" as follows: "let us, having considered the value of a function of x, proceed to consider the alteration which will arise if $x+h$ be written instead of x."

INCUBATION, ARTIFICIAL. [POULTRY.]

INCUMBENT. [BENEFICE.]

INDEFINITE means "not given or defined in magnitude." Thus, a definite straight line is that of which the extremities are known; an indefinite straight line (in length) is one of which the direction is given, and which may be supposed to have any length, or which can be lengthened if necessary, without contravening any of the conditions of the problem. Thus, Euclid, in the first book, constructs an equilateral triangle upon a definite straight line, and shows how to draw two lines making with one another the same angle as that made by two given indefinite straight lines.

There is, however, a reprehensible use of the word indefinite, which is found in many mathematical works; namely, the employment of it to avoid the odium which attaches to the word infinite. Thus we hear of making a magnitude indefinitely great, of an indefinitely small arc being equal to its chord, of the circle being a polygon of an indefinitely great number of sides. In all these cases it would be better, with a proper definition, to use the word infinite at once.

A want of proper distinction between definite and indefinite sometimes leads to confusion. For instance, it is said that if a straight line be halved, if its half be then halved, and if fresh portions be continually taken, each of which is the half of the preceding, the result will at last become less than "any line which can be named." This is not true if the line which is to be named be indefinite; that is, if we may at any part of the process make it as small as we please; for it is obvious that whatever a line may be, a smaller line can be named. But it is true of a definite line, made definite, or given in length, at the beginning of the process: name any line, however small, but such as you name let it remain; then, by continually halving any other line, however great, you must at last arrive at a line which is less than the length you named. The phraseology of a line "less than any line which can be named" has often caused a difficulty by not specifying the time at which it is to be named. The language used by Euclid himself is as follows (book x., prop. 1), and is free from the ambiguity in question: "Two unequal magnitudes being given, if from the greater be taken away its half, and from what is left its half, and if this be done continually, a magnitude will at last be found which is less than the lesser of the two given magnitudes."

INDELIBROME. [INDIGO.]

INDENTURE. [DEED.]

INDEPENDENTS, or CONGREGATIONALISTS, the name of a sect, class, or denomination of English Protestant Dissenters, one of the three who united form the Three Denominations, the other two being the Presbyterians and the Baptists.

When the principle of resistance to the power which maintained at least an outward and specious uniformity of Christian practice and opinion had received encouragement and was successful, it was not to be expected that nations who recognised that principle would agree among themselves respecting what should be done in their new condition of religious freedom. In England the politicians of the time soon succeeded in establishing a national church with pastors and bishops, and the church has been maintained in that form and order from the time of the Reformation, with the slight exception of the period of the Commonwealth. But there were many people in England who objected to several things which made a part of the constitution of that church; and as their objections consisted very much in the desire of what they considered a greater degree of purity in its forms, they were called in derision Puritans and Precisians, in which allusion was also included to the greater strictness with which they observed their religious duties, and their supposed peculiar preciseness in respect at once to an exactness of conformity to scripture precedent and to the obligations of a severe morality.

These persons were not all of one mind within themselves. Many uniting with these distinguishing characteristics the principle that, there being no scriptural authority for the Episcopal order, the government of the church or the superintendence of its ministers ought to be vested not in an individual, but in synods and presbyteries; these formed the Presbyterians. There were others who would have no union or government of the church, who regarded each congregation of faithful men as being in itself a church, and when properly constituted with deacons and a pastor forming a body which was independent of every other, and competent to its own direction and government without any interference from presbyteries, bishops, or from the state itself; this is the pure principle of English Independency.

Robert Brown, a clergyman of the reign of Elizabeth, is generally reputed to be the first person in England who publicly avowed this opinion, and acted upon it by the establishment of various such separate churches, which however had no enduring existence. There is some question whether he retained his opinions to the last: but it is certain that after he had given no small trouble to the authorities in the church, he was presented to the living of Achurch in Northamptonshire. He closed a long and very troubled life in the jail at Northampton, or very soon after he had left it, in 1630. [BROWN, ROBERT, in BIOG. DIV.]

Other persons, and some of them of celebrity in the history of the Puritans, adopted the opinion, but were restrained from acting upon it by the laws then in force for maintaining the Church of England as then established. But when Episcopacy was abolished and Monarchy had been overcome, there was a large party of these Independents which suddenly presented itself, who had a great share in the struggle then being made, and who were the means of preventing the establishment of a Presbyterian church in England, which it was the object of by far the larger portion of the Puritan body taking part in the contest to form. Cromwell belonged to the Independents. Dr. John Owen, dean of Christ Church, who was also for a time vice-chancellor of the University of Oxford, is considered as the chief ornament of this denomination at the time (the Commonwealth) when it first became considerable. [OWEN, DR. JOHN, in BIOG. DIV.]

What the issue might have been of the struggle between the principle of Independency and the principle of Presbyterianism cannot now be told, the king being soon restored, and with him the Episcopal church. In 1662 the Act of Uniformity was passed, the object of it being to exclude from the ministerial office in the Church of England divines of either of those opinions. The act required a direct acknowledgment of the principle of Episcopacy. The effect of it was, that about 1900 ministers retired from the places they held in the church. Some make them 2000. These are the ministers whom Dissenters mean when they speak of "the illustrious two thousand," "the ejected ministers," or "the Bartholomew worthies." During the reign of Charles II. every effort was made to prevent these persons continuing to exercise their ministry. But it was all in vain. They, or at least the greater part of them, persisted in preaching, notwithstanding the certain penalties of imprisonment and fine. However, the Revolution of 1688 freed them from these penalties; one of the first acts of the new government being to grant toleration to them, that is, to allow them to open meeting-houses, or chapels, and to conduct the services under the protection of the law.

The Independents were inconsiderable at that time as compared with the Presbyterians. Both however (and the Baptists also) built chapels for themselves and formed themselves into congregations, called the Presbyterian congregations and the Independent congregations; and each denomination had its own board or fund.

The 'Act of Toleration' was passed in 1689, and for the seventy years succeeding that date the Independent denomination dwindled (as indeed did the whole body of Dissenters), and it was in a very low condition when the state of things arose which we have now to describe.

About the middle of the 18th century there was an extraordinary revival of religious zeal under the influence created especially by the Wesleys and Whitefield. The Dissenters, like the Church, had adopted pretty generally the principle that to inculcate the moral duties, to present the paternal government of God as a source of consolation and of hope, to hold out the prospect of future accountableness and of eternal life, to show the evidence on which we receive Jesus Christ as the minister and messenger of his heavenly Father, were the principal subjects on which it was the duty of Christian ministers to insist. This it was easy to represent as an abandonment of the distinctive truths, as they are sometimes regarded, of Christianity; and many persons, under the preaching above alluded to, were disposed so to regard it, and to seek a ministry by whom these distinctive truths would be made more prominent. Most of these persons joined themselves to the Wesleyan Methodists, or to the Whitefieldian Methodists (since better known as the Countess of Huntingdon's Connexion); but there were many who declined to unite themselves with any of these bodies, and formed themselves into separate churches upon the Independent principle. These new societies incorporating with themselves the small remains of the old Independents of England,—who, in some instances had, throughout the period by some called the period of Religious Indifference, adhered to the original opinions of the Puritan body at large, which were Calvinistic, and had continued to make those opinions prominent in the public services,—or joining themselves to such decayed and decaying churches, gradually increased in numbers and influence, and constitute at the present day the large body of Dissenters called Independents or Congregationalists.

From the accession of George I., in 1714, when the London dissenting ministers of the three denominations (Presbyterian, Independent, and Baptist) presented an address to the king [WILLIAMS, DANIEL, D.D., in BIOG. DIV.], the three bodies have been accustomed to act together, by their appointed deputies, in reference to great public questions. Most of the old Presbyterian denomination in England having in the course of time adopted Unitarian sentiments, their representatives at length withdrew from the board. The distinctive appellation of "The Three Denominations" is however still kept up, the place of the retiring Presbyterians being occupied by representatives of those Presbyterians in England who hold the views of the Presbyterian churches of Scotland.

The Congregationalists have numerous chapels in London and in various parts of the country. They have also several institutions for the education of their ministers. They still maintain the principle of Independency; are in general strongly opposed to a national establishment, whether Episcopal or Presbyterian; and in doctrine vary, from the high Calvinism of the Savoy Confession, which exhibits the doctrines held by the Independents of the time of the Commonwealth, to the most moderate form of orthodoxy.

The number of Independent ministers is about the same as the number of chapels. The following is a list of the colleges and academies which are exclusively confined to the education of ministers for the Congregationalist denomination. Some of them have valuable endowments; others depend upon annual subscriptions for their support:—

Western college, Plymouth, founded about 1752; number of students, 21.

Rotherham college, Masborough, Yorkshire, founded in 1756; number of students, 17.

Brecon college, founded in 1760; number of students, 25.

Cheshunt college, founded in 1768; number of students, 25.

Airedale college, near Bradford, Yorkshire, founded in 1784; number of students, 20.

Hackney seminary, Middlesex, founded in 1796; number of students, 13.

Lancashire college, founded in 1806; number of students, 20.

Spring Hill college, Moretey, Birmingham; founded in 1838; number of students, 21.

New college, St. John's-wood, London, founded in 1850, by the union of the Coward, Homerton, and Highbury colleges; number of students, 55.

Connected with the Independent body there are also the Board of Congregational Ministers of London and the vicinity; the Congregational Board of Education, which maintains at Homerton a Normal school for the training of day school teachers; the Congregational Library in Bloomfield Street, London; and other institutions of an educational character. The Congregational Union of England and Wales, and the Congregational Union of Scotland, are voluntary associations of ministers and members of the Independent churches, which hold assemblies or conferences yearly, or half yearly, as circumstances may require, for mutual consultation; but not claiming any ecclesiastical authority over their members or churches. The managers and missionaries of the London Missionary Society chiefly belong to the Independent denomination.

There are also a Theological Hall of Congregational Churches at Edinburgh, founded in 1811; with 13 students; and a Presbyterian college at Caermarthen, founded in 1719; with 23 students.

The foregoing statistics are taken from the 'Congregational Year Book,' for 1860; which also states that there are 1600 churches of this connexion in England, 636 in Wales, 147 in Scotland and the Channel Islands, and 208 in the colonies. The ministers and missionaries throughout the British empire are estimated at 2734. In the United States there are said to be 2369 Congregationalist churches, and 2408 ministers.

INDETERMINATE, a word which is mostly applied in mathematics, not to the character of a magnitude, but of a problem. A question is said to be indeterminate when it admits of an infinite number of solutions: if the number of solutions, few or many, be finite, the problem is sometimes, but rarely, called indeterminate. The word indeterminate is also applied to the co-efficients of an assumed form of expansion, and the investigation by which they are then found is called the "method of indeterminate co-efficients." But when thus used the word means nothing more than unknown, and the co-efficients are unknown or undetermined quantities. In the French mathematical writings, the word *indeterminé* should sometimes be translated by indeterminate, sometimes by arbitrary, and sometimes by undetermined or unknown.

INDEX OF REFRACTION. [Light; Refraction.]

INDEX EXPONENT. [Binomial Theorem; Power.]

INDIA, ARCHITECTURE OF. The architecture of India does not extend back to a very remote period. Not only are there no architectural remains of the aboriginal races of Hindustan, but none are known to exist which can be assigned to the Aryan occupants. The earliest known buildings are of Buddhist origin, and are now considered by the best authorities to belong to the 3rd century B.C. When Buddhism was replaced by Brahmanism as the dominant form of religion, architecture underwent a considerable change; and it was again greatly modified by the Mohammedan invasion: but the original Buddhistic type or character was never wholly lost. Minor varieties and local modifications might easily be pointed out, but it will suffice for a broad view of the architecture of India to regard it as Buddhistic, Brahmanic, and Mohammedan.

In looking at the architecture of India most inquirers have been struck with its obvious affinity to that of Egypt; and perhaps a comparison of some of the resemblances and distinctions existing between Egyptian and Indian architecture, will facilitate our explanation of the latter. In the article on Egyptian Architecture we referred rather to points of difference and contrast between that style and the Grecian, than to anything of positive similitude, they being separated from each other by an exceedingly wide interval as to all that regards feeling and taste. The Egyptian and Indian styles, on the contrary, seem to come in contact with each other, agreeing most in those points wherein they most differ from Grecian and from modern taste. If there existed no other resemblance between the architecture of the two regions, there would be a decidedly strong one in their hypogea, or subterraneous cavern-structures hewn out of solid rock, works therefore more properly of exstruction than of construction, and to which, no doubt, ought to be ascribed the chief peculiarities of the styles originating in them, namely, extraordinary massiveness of bulk and proportions coupled with no less singular capriciousness of form. Where the forms are produced by cutting away instead of putting together and building up, they may be shaped quite arbitrarily, moulded according to fancy alone, because they still belong to one naturally coherent mass: whereas were the same forms worked out of separate pieces of material, not only would they frequently be at variance with security and stability, but they would occasion an enormous waste both of material and labour; the difference between the process of exstruction and that of construction being, that in the former the solids are only left after the operation of taking away, while in the latter they are produced by what is built up. This, in our opinion, goes far towards accounting for the various capricious, not to say unmeaning shapes we meet with in many of the columns of the cavern-temples of India; and these again, account for the similar taste which was manifested in later works of construction, a taste so remote from our own that the two can hardly be said to have any sympathies in common.

But in looking at even these rock-caves in detail, we find marked distinctions as well as broad resemblances. Thus while the shafts of the supporting columns have in the Egyptian examples no pedestals, and scarcely anything amounting to a distinct base,—and however much the column itself may be ornamented, the capital is plainly distinguishable from the other parts,—in the Indian cave-temples the columns often appear composed of fragments capriciously put together, it being nearly impossible to determine where their pedestals terminate and their shafts commence, or how much of these latter belong to the capitals. Another circumstance to be noticed, as in this instance constituting a striking point of difference from the practice of the Egyptians, is, that the columns are placed so far apart, and so stragglingly, as to resemble only occasional props, instead of a continued colonnade. In this respect however there appears to have been no fixed system, for in other examples the columns are placed so close together that parts of their capitals almost touch. Again the Indian cave-temples present a marked difference from those of the Egyptians in making in many of them an approximation to a regular vaulted ceiling, while the Egyptian edifices are all covered with flat horizontal ceilings. On the other hand, the affinity between the architectural taste of the two people is strongly marked by the prevalent use we observe, in the edifices of both, of colossal statues placed against piers or walls, sometimes quite attached to or sculptured on them; and which may therefore be considered quite as much to constitute part of the general embellishment, as to be specific objects of worship. In both too we find frequent use of Caryatid figures, or such as serve as columns; and either entire figures or the upper parts of them, both human and animal, enter abundantly into the composition of Indian columns and capitals: in this latter respect, however, as in some others, the architecture of India has more resemblance to that of Assyria than even to that of Egypt. A strong similarity also observable in the general disposition of the sacred buildings of the Indians and Egyptians is, that the former, like the latter, have generally an open or unroofed court before them (sometimes formed by clearing away the rock itself), leading to a vestibule, nave, and sanctuary, progressively diminishing in size. Neither is it uncommon in the excavated temples to meet with a series of small chambers along their sides, increasing their otherwise strong similarity of plan to those of Egypt. The profusion of inscriptions and symbolic sculptures on the walls affords also another characteristic point of resemblance.

Again in looking at constructive works, or edifices erected above ground, we can hardly avoid being struck by the prevalence of pyramidal masses and forms, as exhibited in pagodas, or towers, however great may be the difference in all except the general forms. One broad distinction however is, that, however highly enriched many Egyptian buildings may be, the mode of decoration employed in them is not of a kind to interrupt the simplicity of the outline, it being almost entirely *superficial*, that is, merely enriching surfaces, as a pattern wrought upon them would do; whereas the Hindus seem frequently to have affected the extreme both of massiveness and lightness in the same design, attaching very slender and merely ornamental pillars to enormous piers, which are the real supports.

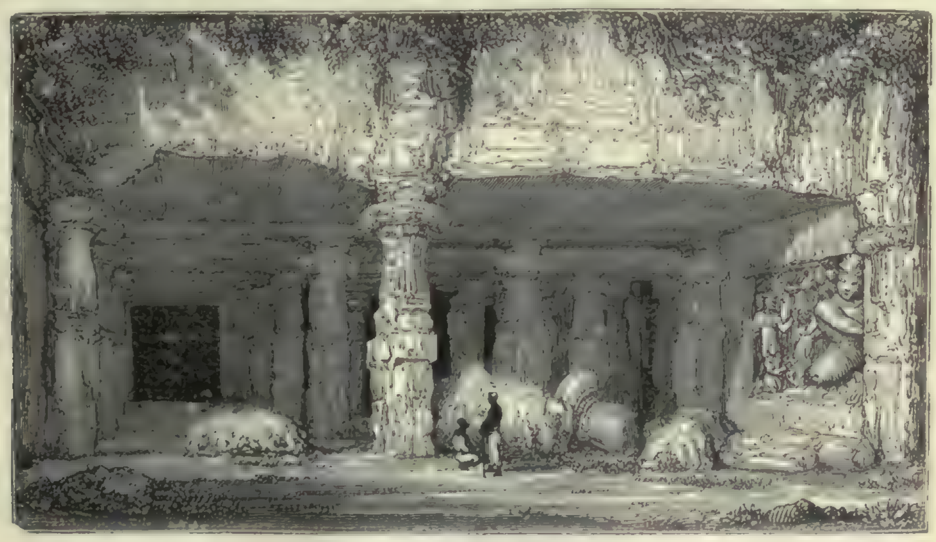
Buddhist Architecture.—Of constructed Buddhist temples proper there are unfortunately no examples left. Topes or relique-houses, some of them of large size, are indeed frequent: but the only true Buddhist temples remaining in India are those excavated out of the solid rock. These subterraneous edifices, combining often, like our own mediæval cathedrals and monastic establishments, a temple with an establishment for the attendant ecclesiastics, occur in surprising numbers, and, considering their age and the fact of their having belonged to a persecuted faith, they are in a remarkable state of preservation. They occur, not only singly, but in groups of from ten to a hundred distinct excavations, and there are in all perhaps not less than fifty of these groups in various parts of India: nine-tenths of those now known being found, according to Mr. Fergusson, within the limits of the Bombay presidency. The oldest are considered to be those of Behar and Cuttack; among the most remarkable are those on the Island of Elephanta near Bombay, at Kennareh, in that of Salsette; those at Ellora near Dowletabad; at Perwatam on the Kistna; those near the pass of Ajanti, and those at Carli, about 30 miles north-west of Poonah. Many of these excavations are of great extent, being composed of a series of apartments and recesses cut out of the rock. Merely as monuments of human labour and perseverance the works of this class would be astonishing, but it is their stupendousness combined with magnificence, barbaric and frequently monstrous, that imparts to them a character almost sublime. As if to imitate nature in her most minute as well as her grandest productions, while colossal statues and sculptures display themselves within these cavern-temples and on their walls, elaborate embellishments of detail are frequently given to the columns, which, as we have said, appear composed of fragments capriciously put together; what is sometimes described as a pedestal supporting the column, might with as much propriety be termed its lower portion, although square or polygonal, while the rest of the shaft is circular.

The rock-temple of Carli, one of the largest and most complete, and one of the oldest of these excavations, will serve to give a notion of their general form and character: we borrow our account of it from Mr. Fergusson, who has personally examined and described it, and indeed all the rock-temples of India; and whose exact as well as extensive knowledge of European as well as Asiatic architecture, renders his descriptions of especial value. In plan it is much like an early Christian church or basilica, "consisting of a nave and side aisles, and terminating in an apse round which the aisle is carried. The general dimensions of the interior are 126 feet, from the entrance to the back wall, by 45 feet 7 inches in width, from wall to wall. The side aisles, however, are very much narrower than in Christian churches, the central one being 25 feet 7 inches, so that the others are only 10 feet wide, including the thickness of the pillars. As a scale for comparison, it may be mentioned that its arrangements and dimensions are very similar to those of the choir of Norwich cathedral, or of the Abbey-aux-Hommes at Caen, omitting the outer aisles in the latter buildings. The thickness of the piers at Norwich and Caen nearly corresponds with the breadth of the aisles in the Indian temple. In height, however, Carli is very inferior, being only 42 or perhaps 45 feet from the floor to the apex, as nearly as can be ascertained.

"Fifteen pillars on each side separate the nave from the aisles; each of these has a tall base, an octagonal shaft, and richly ornamented capital, on which kneel two elephants, each bearing two figures, generally a man and a woman, but sometimes two females, all very much better executed than such ornaments usually are. The seven pillars behind the altar are plain octagonal piers, without either base or capital, and the four under the entrance gallery differ considerably from those at the sides. These sculptures on the capitals supply the place usually occupied by frieze and cornice in Grecian architecture; and in other examples plain painted surfaces occupy the same space. Above this springs the roof, semicircular in general section but somewhat stilted at the sides, so as to make its height greater than the semi-diameter. It is ornamented even at this day by a series of wooden ribs, probably coeval with the excavation, which prove beyond the shadow of a doubt that the roof is not a copy of a masonry arch, but of some sort of timber construction which we cannot now very well understand."

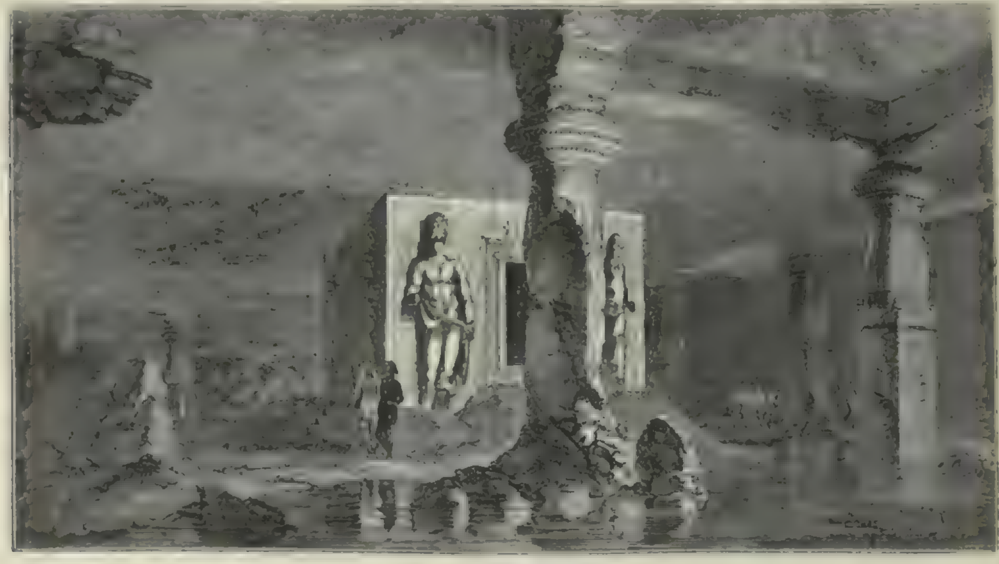
The shrine of the deity, a plain cupola on a circular drum, stands "immediately under the semi-dome of the apse, and nearly where the altar stands in Christian churches." At the opposite end under a gallery is the entrance, consisting of a central door, and one on each side leading into the aisles. Above the gallery the hall is entirely open, the opening looking like a great window with a horse-shoe arch; and through this window the whole of the light enters. A porch outside is seven feet wider than the body of the temple. It is closed in front by two thick octagonal pillars which support a plain mass of rock, but which Mr. Fergusson thinks was formerly ornamented by a wooden gallery, and surmounted by a dwarf colonnade or attic, and crowned with a cornice or some other ornament. In front of the porch stands the lât or lion-pillar (which appears always to have stood in front of the sacred buildings), which bears four seated lions, instead of the usual solitary animal. Of the effect of the exterior it is now difficult to form an adequate conception, but, says Mr. Fergusson, "the proportions of such parts as remain are so good, and the effect of the whole so pleasing, that there can be little hesitation in ascribing to such a design a tolerably high rank among architectural compositions. Of the interior we can judge perfectly, and it certainly is as solemn and grand as any interior can well be, and the mode of lighting the most perfect—one undivided volume of light coming through a single opening overhead at a very favourable angle, and falling directly on the altar or principal object in the building, leaving the rest in comparative obscurity. The effect is considerably heightened by the closely set and thick columns that divide the three aisles from one another, as they suffice to prevent the boundary walls from ever being seen, and, as there are no openings in the walls, the view between the pillars is practically unlimited."

The better known rock temple of Elephanta, or Goripura (the Mountain city), as it is called by the natives, is of later date and larger dimensions. It is magnificently situated, being excavated about half way up the side of a mountain, and in the midst of scenery of more than ordinary grandeur. The entrance, which is hewn out of a stone resembling porphyry, is by a spacious front, which is supported by two massive pillars (one of which has fallen), and two pilasters, forming three openings, under a thick and steep rock overhung by brushwood and wild shrubs. "The whole excavation consists of three principal parts: the great temple itself, which is in the centre, and two smaller chapels, one on each side of the great temple. These two chapels do not come forward into a straight line with the front of the chief temple, are not perceived on approaching the temple, and are considerably in recess, being approached by two narrow passes in the hill, one on each side of the grand entrance, but at some distance from it. After advancing to some distance up these confined passes, we find each of them conduct to another front of the grand excavation, exactly like the principal front which is first seen; all the three fronts being hollowed out of the solid rock, and each consisting of two huge pillars with two pilasters. The two side fronts are precisely opposite to each other on the east and west, the grand entrance facing the north. The two wings of the temple are at the upper end of these passages, and are close by the grand excavation, but have no covered passage to connect them with it." (Erskine.)



Entrance to the Temple at Elephanta.

"From the northern entrance to the extremity of this cave is about 130 feet, and from the east to the west side 133 feet. Twenty-six pillars, of which 8 are broken, and 16 pilasters, support the roof. Neither the floor nor the roof is in the same plane, and consequently the height varies, being in some parts 17½ feet, in others 15 feet. Two rows of pillars run parallel to one another from the northern entrance, and at right angles to it, to the extremity of the cave; and the pilasters, one of which we have described as standing on each side of the two front pillars, are followed by other pilasters and pillars also, forming, on each side of the two rows already described, another row running parallel to them up to the southern extremity of the cave. The pillars on the east and west front, which have been described as like those on the north side, are also continued across the temple from east to west. Thus the ranges of pillars form a number of parallel lines intersecting one another at right angles, the pillars of the central parts being considered as common to the two sets of intersecting lines. The pillars vary both in their size and decorations, though the difference is not sufficient to strike the eye at first. Each column stands upon a square pedestal and is fluted, but instead of being cylindrical is gradually enlarged towards the middle. The capitals exhibit that bulbous form which is one of the most distinctive characteristics of Indian architecture. Above the tops of the columns a kind of ridge has been cut to resemble a beam about 12 inches square, and this is richly carved. Along the sides of the temple are cut between 40 and 50 colossal figures, varying in height from 12 to 15 feet; none of them are entirely detached from the wall. Some of these figures have on their heads a kind of helmet; others wear crowns with rich devices; and others, again, are without any other covering than curled or flowing hair. Some of them have four and others six hands, holding sceptres, shields, symbols of justice, ensigns of religion, weapons of war, and trophies of peace. On the south side, facing the main entrance, is an enormous bust with three faces; of which the central face measures 5 feet in length; the width from the ear to the middle of the nose is 3 feet 4 inches; the breadth of the whole figure is near 20 feet. To the left of this bust, amid a group of uncouth figures, is one (a female figure with four arms) to which Niebuhr has given the name of Amazon, from the fact of its being without the right breast. At the west side of the temple is a recess, 20 feet square, having in the centre an altar, upon which are placed symbols of the worship once practised here. The entrance to this recess is guarded by eight naked figures, each 13½ feet high, sculptured in a manner which shows that the people by whom they were executed must have made considerable progress in the statuary's art. The cave is not at present used as a temple, nor has it any establishment of priests connected with it, although it is frequently visited by devotees for the purpose of offering prayers and oblations.


Temple of Elephanta.

The roof of the temple at Elephanta is flat; in others it is hollowed out so as to resemble more or less a regular vaulting. Of this last-mentioned kind is the temple of Kennarch, or Canarah, in Salsette, which is exactly on the same plan as that at Carli, and the principal object or idol is alike in both, consisting, as Moor describes it, "of a vast hemisphere of stone resting on a round pedestal of greater diameter having its convexity surrounded by a sort of canopy or umbrella of peculiar construction." The ground-plan of an arched temple of Buddha at Ellora is exactly similar, but there is here a figure of Buddha himself in front of the cylindrical pedestal and characteristic umbrella ornament just mentioned. The temple at Salsette Mr. Fergusson is inclined to reckon among the latest of the Buddhist edifices of this class, regarding it as a copy of the temple at Carli, and as late in date as the 9th or 10th century of the Christian era.

The Buddhist rock-cut monasteries are much less rich in detail than the temples. They consist of a central hall, around which are numerous plain cells for the priests of various grades. There were places for private devotion; the public worship and more imposing ceremonies were performed in the temples. The oldest of these caves occur at Behar, in the Bengal presidency, but they are quite unornamented. At Cuttack is one known as the Tiger Cave, from the exterior being carved into the form of a tiger's head, the entrance being through the animal's open mouth. Another in the same neighbourhood is distinguished by being two stories in height, and having a verandah carved along the whole extent of its front. Dr. Impey has published a full account of a series of Buddhistic caves at Koolvee, in Central India, which are "cut literally round the circumference" of a hill, and are in all about fifty in number. Among them are six dagobas (or relic-chambers), connected with each of which is a *shala*, or hall of assembly, and a larger cell for a superior priest. Two only of the caves are supported by pillars, and these are each 32 feet by 24 feet. "One of these caves is subordinate to a dagoba, which stands in a court-yard in front of it, flanked by an erect colossal figure of Budh, in the attitude of expounding; and the other to a seated image of Budh, which is in a cell opposite the porch flanked on either side by diminutive dagobas in relief." The figures are of rude execution, and much defaced and weatherworn. The inferior cells are all small in size and quite simple in plan.

The walls of the larger chambers of some of these rock-monasteries are profusely decorated with paintings of religious and historical subjects, executed in fresco or distemper, portraits of Buddhs and Buddhist saints covering the pillars, and the roofs being at the same time painted with scrolls and other architectural designs. In many places these paintings have been destroyed by the effects of damp, or by the hand of man, but at the Ajunta and elsewhere they "remain nearly complete, and as fresh as the day they were painted. A competent artist, Capt. Gill, of the Company's Service, has been employed for some years in copying these." Their publication would doubtless, as Mr. Fergusson remarks, throw light not only on the "manners and customs of India more than a thousand years ago, but illustrate also to a considerable extent the form and ordinance of the buildings they adorn." Dr. Impey ('Journal of the Royal Asiatic Society,' Bombay Branch, July, 1856,) describes a series of historical and mythological paintings on the famous caves of Bágh in Rath, on the Nerbudda, which still extend above 220 feet in length. The paintings are in a double row, one set above the other, the figures being about the natural height. The designs are very varied, and display no little skill. "The surface extent of the work thus elaborately depicted must have been at least 3000 feet." They appear to be not later in date than the 5th century, A.D.

The other Buddhist religious edifices have been all classed under the general term *Topes*. They consist of detached pillars and towers, and of buildings, usually circular in form but always surmounted with a dome. The pillars are the oldest. All that remain in India proper are monoliths, but there appears to be little doubt that built pillars did formerly exist; and Mr. Fergusson, who adduces two such pillars as still standing among the topes of Cabul, thinks that their destruction is "sufficiently accounted for by the ease with which they could be thrown down and their materials removed, when they had lost the sanctity by which alone they had been protected." Of these monoliths, or lâts, the oldest known were erected by Asoka about 250 B.C., and bore inscribed on them the Buddhist creed. Three of them are still standing near the river in Tirhut, and are each surmounted by a seated lion. One which has been removed and set up on a pedestal at Allahabad, is 47 feet high, and the shaft is 3 feet in diameter at the base, diminishing to 2 feet 2 inches at the summit. It is noteworthy that "the necking immediately below the capital represents, with considerable purity, the honeysuckle ornament of the Assyrians." (Fergusson). They were most probably always erected in front of temples and sanctuaries, where some are still found.

The topes properly so called are spacious circular domical buildings, erected as reliquaries of Buddha or some of the more eminent Buddhist saints. They occur in groups near the Indus and the Ganges, at Behar and Tirhut, around Bhilsa in Central India, and in Affghanistan. These topes will be found fully described in the valuable works of Mr. Fergusson, and in the elaborate treatise of Major Alexander Cunningham, 'The Bhilsa Topes; or Buddhist Monuments of India,' 8vo. 1854. The oldest of these topes are little more than tumuli; later the hemispherical cupola was supported on a cylindrical basement; and eventually they assumed the character of a tower surmounted with a cupola. In size they vary from a few feet up to 150 or 200 feet in diameter. The great Sanchi Tope, near Bhilsa, the finest and most perfect in India, will serve as an example of this class of buildings. It is situated on the western side of a lofty hill, and is inclosed within a great court-yard which averages 150 yards in length, and is 100 yards broad. "The great tope itself is a solid dome of stone and brick, 106 feet in diameter and 42 feet in height, springing from a plinth of 14 feet, with a projection of 5½ feet from the base of the building, and a slope of 2½ feet. The plinth or basement formed a terrace for the perambulation of worshippers of the enshrined relic; for on the right pillar of the North Gateway there is a representation of a tope, and of two worshippers walking round it with garlands in their hands. The terrace was reached by a double flight of steps to the south, connected by a landing ten feet square. The apex of the dome was flattened into a terrace 34 feet in diameter, surrounded by a stone railing of that style so peculiar to Buddha monuments, that I will venture to call it the Buddhist Railing." This terrace formed the basis of the *tee* or capital (a square box-like ornament probably intended to serve as a relique-case or a symbol of one) with which these structures were always crowned. "The total height of the building, including the cupolas," continues Major Cunningham, "must have been upwards of 100 feet. The base of the tope is surrounded by a massive colonnade, 144½ feet in diameter from east to west, and 151½ from north to south." The entrance is by four gateways, each formed by two square pillars, 18 feet high, covered with carvings, and crowned with elephant capitals. These support three elaborately carved lintels slightly curved upwards in the centre, and terminating in Ionic scrolls and surmounted with emblems: in all the gateways are 33½ feet high. On all sides are ruined temples, fallen columns, and broken sculptures; while 30 or 40 smaller topes combine to form the group of which the great tope is the centre.

With respect to the character and arrangement of the topes, it will be enough to quote what Major Cunningham says of those of Bhojpur: "The topes occupy four distinct stages or platforms of the hill. The largest topes, six in number, occupy the *uppermost* stage, and were, I believe, dedicated to Buddha; that is, either to the celestial Buddha, *Adináth*, or to the relics of the mortal Buddha, *Sákya*. This view is borne out by the facts that the largest tope contained no deposit; and that the second and third sized Topes yielded crystal boxes, one of which, shaped like a tope, contained only a minute portion of human bone smaller than a pea! The second rate topes, sixteen in number, stand on the second stage. According to my view, these topes contain the ashes of those who had reached the rank of Bodhisatwa. We discovered relics in five of these topes, but there were no inscriptions of any historical value. The third stage of the hill is occupied by seven small topes, all of which I suppose to have been built over the remains of the third grade of Pratyeka Buddhas. Of the eight topes which stand on the lowest stage of the hill, one is much larger than any of those on the third stage. These topes were, I believe, built over the ashes of the lowest grade of the Buddha community, the Sráwaka Buddhas."

Very splendid examples of Buddhist temples, topes, and dagobas occur, at Anuradhapoora, the ancient capital, and in several other places in the island of Ceylon. These, from their having escaped the destructive hand of adverse religious bodies, serve to elucidate many interesting points in the history of Buddhist architecture which the remaining monuments of the peninsula leave in obscurity. Our space will not, however, allow us to notice them here: they will be found described in the works of Mr. Fergusson and Sir Emerson Tennent. In Burmah also occur numerous costly Buddhist edifices, some of them on a scale of great magnitude, as the great pagoda of Pegu—a comparatively modern structure—the diameter of whose base is 395 feet, while its height is 331 feet above the artificial terrace on which it stands. At Java again are several vast Buddhist temples, as that of Boro Buddor, which is a square nine-storied many-pinnacled pyramid, the base of which is 400 feet across. In style, however, these last are far more barbaric than the older buildings of Hindustan.

Based on the Buddhist style, but much more highly ornamented, are the temples erected by the Jainas, the great sect which sprang up at the decline of the Buddhists. [JAINAS.] Some of these temples are distinguished alike by chasteness, symmetry, and beauty of design, and by rich and exquisite finishing. That at Ajmeer, in Rajpootana, is remarkable for the elegance and slenderness of its columns, so very different in their character from those in the excavated works, and which seem therefore to indicate a totally different period of art. They are about forty in number, and partake somewhat of a candelabrum shape, although no two are exactly alike. The ceiling is highly enriched with square panels or coffers, containing others in the form of lozenges, enriched with foliage and sculpture, in style not very much unlike the *cinquecento* of the Italians. This temple is surrounded by a superb screen of Saracenic architecture, assigned by Tod to the first dynasty of the Ghorian Sultans. The same writer dwells upon the analogy observable between the details of the columns in this temple and the ornaments of Gothic buildings; and it would hardly be fanciful to designate Jaina architecture the Decorated Buddhist style. Some of the oldest and finest examples of the style are found about Mount Abu in Gujerat, but they occur over a wide space, though often altered, like the temple at Ajmeer, by Mohammedan additions. The temples appear always to include a sanctuary, lighted only from the door, and terminated upwards by a pyramidal spire-like roof. In this chamber is placed a seated figure of the saint to whom the temple is dedicated; and attached to it is a spacious portico, which is sometimes surmounted by a cupola. These porches are often extremely rich in ornamentation: that of the temple of Vimalah Sah at Abu (described and figured by Mr. Fergusson) has 48 elaborately carved columns; yet the exterior of the temple is perfectly plain. The Jainas were the first to erect hollow cupolas in India, those in the Buddhist topes being all solid. The cupolas of the Jaina temples are formed by placing the stones so as gradually to project one beyond the other, the apex being closed by a circular key-stone. The principle therefore is that of a horizontal or vertical instead of a radiating pressure, and the edges of all these projections being rounded off, the spectator sees, on looking up, a vault composed of gradually diminishing circles or annular courses of masonry. Brackets and struts are occasionally employed with great skill to assist in bearing the superstructures. According to Mr. Fergusson, some of these Jaina cupolas are "the most exquisite specimens of elaborate roofing that can anywhere be seen." Usually the octagonal cupolas are carried on eight thick pillars; but the base is always made square by the addition of four other pillars at the angles; while in smaller buildings two more are added on each face, making twenty in all. "Sometimes, however, the same system of aggregation is carried on till the number reaches fifty-six, which is the largest number I ever saw surrounding one dome; but any number of these domes may surround one temple, or central dome, and the number of pillars consequently be multiplied *ad infinitum*." (Fergusson.) The variety, picturesqueness, and splendour of effect, and the rich play of light and shade, thus produced, however impure the style of architecture may be in itself, can readily be imagined. Many of the most superb of the Jaina temples have been converted into Mohammedan mosques.

The Jainas appear to have also wrought out cave-temples; among others the Subba caves of Ellora have been attributed to them; but there is nothing in their works of this class sufficiently distinctive to call for a particular description.

Following their Buddhist predecessors, the Jainas showed a great partiality for erecting towers; and their towers, though less substantial, were little less rich than their temples. Few of them however are left now. Two of them still stand within the fort of Chittore. The older and smaller is of the 10th century, A.D.; the larger is of the 15th. This last is 30 feet wide at the base; 120 feet high; and is formed in nine stories, the whole being covered with architectural and sculptural ornament. The body, or shaft, of the tower is smaller than the base, but it swells out again towards the summit, which is surmounted with a small dome, and which was probably crowned with a tee. It is fully described and figured in Mr. Fergusson's 'Illustrations of Indian Architecture,' and 'Handbook of Architecture.' This class of dagoba is the immediate prototype of the Chinese nine-storied pagoda.

Brahman Architecture is best studied in the temples of Southern India. In Northern India the style is a good deal varied and less pure. What may be considered as the normal type of a Brahman temple consists of the *vimana*, a tower square in plan and pyramidal in form, built over the sanctuary or cell in which is the image or emblem of the god; a *mantapa*, or porch, placed before the principal entrance to the sanctuary; *gopuras*, or pyramidal gate towers, which serve as entrances to the enclosures in which the vimanas are placed; and a *choultrie*, or spacious pillared hall.

The Vimana, or inner temple, has a perpendicular base of granite or stone, which is always decorated with pilasters, niches, and other architectural ornaments. From this rises in distinct stages the pyramidal roof, usually constructed of brick and covered with stucco, and crowned with a small dome-like termination, evidently borrowed from the older Buddhist builders. The most splendid example of one of these buildings is the great temple at Tanjore, from the annexed representation of which their general character may be understood. The base of this temple is 82 feet each way, and the pyramidal roof rises in 14 stories to a height of about 200 feet.

The porch, or Mantapa, is in plan usually similar to the temple itself, has a door on each of the four sides, and a pyramidal roof, but much lower than the roof of the temple, unsupported by pillars, and without a crowning ornament. Placed against the door of the cella, the mantapa effectually excludes the light of day from the sacred chamber, which consequently is lighted only by lamps.

Temple at Tanjore.

The Gopuras, or gate-pyramids, which give entrance to the rectangular court which encloses the temple, are usually proportioned in size and number to the length of wall which surrounds the court. Some of these gateways are much larger than the temples to which they are appended, and the entire surface of many of them is covered with ornament. One at Combaconum is 12 stories high. In form they are similar to the vimanas, except that they are not so deep as they are wide, and they are always pierced with a doorway occupying from a fourth to a seventh of the whole width.

"By far the most extraordinary buildings connected with these fanes are the pillared colonnades or Choultries, which occupy the spaces between the various enclosures of the temples. They are of all shapes and sizes, from the little pavilion supported on four pillars up to the magnificent hall numbering a thousand. Their uses too are most various; in ancient times they served as porches to temples; sometimes as halls of ceremony, where the dancing girls attached to the seminary dance and sing; sometimes they are cloisters, surrounding the whole area of the temple; at others swinging porches, where the gods enjoy at stated seasons that intellectual amusement. But by far their most important application is when used as nuptial halls, in which the mystic union of the male and female divinities is celebrated once a year. Those dedicated to these festivals sometimes attain an extent of 1000 columns, and are called in consequence halls of 1000 columns, though they do not in all instances make up this complement." (Fergusson.) The pillars are in most instances composed of granite, and covered with sculpture from the base to the capital, every pillar being usually unlike the others in the details, though similar in general character and dimensions. The effect of many of these halls is very impressive.

As an example of the style of southern Hindustan we may refer to the small but very elegant temple at Bareilly, as a structure of most complicate and exquisite workmanship. Although placed within an area about 250 yards square, the body of the temple, or sanctuary (*mindra*), over which rises a pyramidal *sikr*, or roof, is only 21 feet square, but the addition of the domed vestibule (*munduf*) and the projecting portico composed of four superb columns makes the whole 44 feet by 21. The ceilings are elaborately worked, and that of the portico consists of a single block. Facing this temple is another splendid edifice, called the Séngár-chaori, or Nuptial Hall, a square of about 40 feet, with a double range of pillars on each side forming open colonnades. Its *sikr* is the frustum of a pyramid, each stone of which is elegantly carved, and gradually decreasing in size to the *kullus* or ball.

After the introduction of the Saracenic architecture by the Mohammedan invaders, the Hindu architects adopted in their secular buildings many of the features of the new style. Some of the palaces constructed under this foreign influence are extremely picturesque, as the palace of Madura, commenced in the early part of the 17th century. But the decline of Hindu architecture was thenceforth rapid; innovations of all kinds were introduced, and the native barbaric magnificence, originality, and piquancy were lost, without being replaced by western purity, simplicity, or taste.

The Mohammedans at first, it is evident, were led to imitate much both of the general forms and the details of the ecclesiastical architecture of the people they had conquered. But they brought with them the principle of the arch, and with it a different and more daring style of construction. They never wholly abandoned the forms they had adopted from the Hindus; but they so modified and applied them that ultimately their style became rather a variety of the true Saracenic or Moorish style than of either of the styles of India. Hodges, who has carefully studied the original buildings, indeed refers us to the mosque at Chunar Gur, on the Ganges, as a proof of the "perfect similarity of the architecture of India brought thither from Persia by the descendants of Timur, and that brought into Europe by the Moors of Spain." "All the minuter ornaments," he says, "are the same, the lozenge square filled with roses, the ornaments in the spandrels of the arches, the little panellings and their mouldings; so that a person would almost be led to think that artists had arrived from the same school, at the same time, to erect similar buildings in India and in Europe." This is, however, too strongly put, and is contradicted by the details of his own plates. There are, in truth, many features in the Mohammedan architecture of India which stamp it as distinct from the Moorish style of Europe. [SARACENIC ARCHITECTURE.] Among these are its numerous bulbous domes, which are frequently applied even to minarets, and the projecting galleries given to these latter, to which may be added the use of very projecting balconies, supported on massive cantilevers or consoles. One of the most splendid examples of this later style is the celebrated Taje Mahal, near Agra, erected by Shah Jehan as a mausoleum for his wife in the 17th century. "It stands," says Bishop Heber, "in a square area of about 40 English acres, enclosed by an embattled wall with octagonal towers at the angles, surmounted by open pavilions, and four very noble gateways of red granite, the principal one of which is inlaid with white marble, and has four high marble minarets. The space within is planted with trees and divided into green alleys leading to the principal building, which is a sort of solid pyramid surrounded entirely with cloisters, galleries, and domes, diminishing gradually till it ends in a square platform of white marble, surrounded by a most elaborate lattice-work of the same material, in the centre of which is a small altar-tomb, also of white marble, carved with astonishing delicacy and beauty." The cost of this tomb is said to have been 750,000*l*. An equally celebrated but inferior work of this class is the mausoleum of Hyder Ali at Seringapatam.

Next to the tombs, perhaps, as characteristic of Mohammedan architecture in India, are the mosques, some of which are of considerable magnitude and magnificence. In the gateways, which are made a striking feature, the Moorish arch inclosed within a square-headed panel is applied with excellent effect. In the mosques themselves there is often a great multiplicity of hemispherical or bulbous domes. The mosque at Mandu, the great mosque at Delhi, and the pearl mosque of Shah Jehan at Agra, are very beautiful examples of Mohammedan temples. Some of the minarets are highly enriched and of unusual dimensions; that of Kootub is 48 feet at the base and 242 feet high, though it has lost its capital—being only exceeded among Mohammedan buildings by the minaret of the mosque of Hassan in Cairo.

Still more splendid are, or were, the palaces, which are in some instances of prodigious extent, finished in a style of unbounded luxuriance, full of fanciful and admirably-executed ornamental details, and unquestionably picturesque in appearance. Among the most superb are those of Agra, Allahabad, Lucknow, and Delhi.

INDIAN FIRE. A brilliant white signal-light, produced by burning a mixture of 7 parts of sulphur, 2 of realgar [ARSENIC], and 24 of nitre.

INDIAN INK. [INK.]

INDIAN RUBBER. [CAOUTCHOUC.]

INDIAN YELLOW. [COLOURING MATTERS.]

INDIANS. [NORTH AMERICAN INDIANS.]

INDICAN. [INDIGO.]

INDICATOR. The word *indicator* is used, generically, in mechanical engineering, to designate any contrivance by means of which it is possible to calculate the force exerted by the intervention of a machine; but it has of late years been almost exclusively applied to the instruments by which the pressure of steam in the cylinder of a steam-engine is registered throughout the whole of its duty, or by which the amount of vacuum or exhaustion attained by the use of the air-pump and condenser, is recorded. The indications of the pressure of steam in the boiler are marked by the *pressure gauge ;* the indications of the useful amount of power transmitted to the first motion-wheel are recorded by the *dynamometer ;* whilst the meaning of the generic term is limited to the sense above given. Different constructors have introduced varieties in the form and working details of their indicators; but they all are identical in principle. They are all self-registering, and show (by means of a curve traced on a slip of paper by a pencil attached to the part of the indicator immediately connected with the steam in the interior of the cylinder, or with the vacuum), the difference between the pressure of the atmosphere around the cylinder, and the pressure within the cylinder, at every part of the up and down stroke of the piston, for that end of the cylinder to which the indicator is attached. In order to effect this object, a small cylinder is connected with the larger one in which a steam and air tight piston works, and the rod of this piston passes into another small cylinder, in the interior of which is placed a spiral spring, which in its turn presses upon the rod of the indicator piston in such a manner as to keep the latter in the centre of its cylinder, when the pressure of the atmosphere and of the vapour in the cylinder of the engine balance one another. In proportion as the relative pressure increases on either side of the cylinder of the indicator, it will be found that the piston will rise or fall; for spiral springs (as Messrs. Hann and Gener observe), are extended and compressed through equal spaces by equal and opposite pressures. There is a stud passing from the top of the piston-rod through a slot in the spring cylinder, and an index pointer shows on a scale attached to the side of the slot the pressure acting upon the piston. The description and use of this instrument are well explained in Hann and Gener's book, above quoted, entitled 'The Steam Engine,' 1854, &c. &c.

INDICTION; CYCLE OF INDICTION. [PERIODS OF REVOLUTION.]

INDICTMENT is a written accusation of one or more persons of a crime or misdemeanour presented by a grand jury. The sheriff returns to every session of the peace and every commission of oyer and terminer and jail delivery at least twenty-four freeholders of the county, twelve of whom, at least, and not more than twenty-three, are sworn upon the grand jury. They are instructed in the articles of their inquiry by the judge, and then withdraw to sit and receive bills of accusation, which are presented to them in the name of the crown, but at the suit of any private person. The decision of the grand jury is not in the nature of a verdict as to the guilt of the accused, but merely the expression of their opinion that from the case made by the prosecutor the matter is fit to be presented to the common jury. In conducting the inquiry the evidence in support of the accusation only is heard. If the grand jury think the accusation groundless, they indorse on the bill "not a true bill," or "not found;" if the contrary, "a true bill;" and in finding a true bill twelve at least of the grand jury must concur, because no subject can be put to answer an accusation except such as is credited by such a number of his fellow-citizens. Anciently the words "ignoramus" and "billa vera" were used. When a bill is found to be a true bill, the trial of the accused takes place in the usual form; when the bill is "ignored," the accused is discharged, but a new bill may be preferred against him before the same or another grand jury. Sometimes, when the bill is ignored on account of some slip or error, the judge will direct the accused to be kept in custody, in order to prevent him from escaping from justice.

INDIGESTION. [DYSPEPSIA.]

INDIGO. This well known colouring matter is a product of the vegetable kingdom, being derived from the cellular tissue of the leaves of certain plants. For the names and habitats of these plants, see INDIGOFERA, in NAT. HIST. DIV.

Indigo was well known to the ancients. Bands of cloth, evidently dyed with this material, are met with in the wrappings of Egyptian mummies; and Dioscorides and Pliny mention it as an Indian product under the names of *ινδικον* and *indicum*. It began to be employed in Europe about the middle of the 16th century, but owing to the opposition of the cultivators of the native woad, its importation into England was prohibited; and it was not till the time of Charles II. that these prejudices were overcome. At the present time there are sent into this country from 60,000 to 70,000 cwts. of indigo per annum.

The cultivation of the indigo plants is extensively carried on in various parts of India and America. In the spring the seeds are sown, at the rate of about a dozen pounds per acre; the plants grow rapidly, commencing to blossom in three months time, when they are cropped and again allowed to grow till they are sufficiently mature to admit of another cutting. Occasionally a third and even a fourth cropping is made, but each of these contains successively less and less of the matter that yields the colouring principle.

The indigo plants present no appearance when growing that would lead an observer to suppose they contained any matter capable of producing colour; nor is it yet satisfactorily determined in what form the indigo pre exists in the vegetable tissues. From the recent experiments of Schunk ('Manchester Memoirs,' 1855, vol. xii., p. 177), it would seem that a principle, termed by him *Indican*, of yellow colour, and having the composition (C_5 H[illegible]NO_{36} ?), occurs naturally in the plants, and that it is from the decomposition of this body, under circumstances immediately to be described, that the indigo is produced.

The manufacture of indigo in the East Indies is conducted somewhat after the following plan. The recently cut plants are placed in large stone cisterns, called fermenting vats, or steepers, and covered with water; fermentation soon commences, large quantities of gas rise in bubbles to the surface, and the whole mass becomes covered with a copper-coloured scum. After about fifteen hours fermentation ceases, and the liquor is then run off into another vat placed on a lower level. Here it is brought well into contact with the air by beating with wooden paddles for about an hour and a half. During the beating the contents of the vessel darken in colour, and the indigo separates out in flocks; these are allowed to subside, heated to boiling to effect the removal of certain impurities, then collected on woollen strainers, and finally pressed, dried, and the mass cut up into blocks for sale. At some places the plants are, after cutting, spread out to dry in the sun, it being supposed that a better quality of indigo is thus obtained.

Indigo is usually met with in commerce under the form of cubical masses or cakes, which are brittle and of characteristic colour, a colour that ranges from a deep blue containing a little purple, to a dark purple containing a little blue. When burnished it acquires a beautiful, glossy, copper tint. It is generally thought that its specific gravity should be less than that of water, though the method of preparation and adulteration with foreign matters often cause it to weigh more than an equal bulk of that liquid. Many methods for estimating the absolute amount of colouring matter—*indigotin*—in a specimen of indigo have been proposed, but they all require experience in chemical manipulation for their accurate performance: they will be found described in the various analytical text-books.

The great value of indigo as a dyeing material, and the enormous extent to which it is used, have procured for it a large share of the attention of scientific chemists. The result is that its application as a pigment has been greatly extended, and many important and interesting derivatives obtained from it. The following list will exhibit at a glance the relations which the chief of these derivatives bear to each other. Starting with pure indigo itself (indigotin), which may be looked upon as a positive radical, and which we may represent by the symbol (In=*indyl*), we have :—

Indigo-blue	$C_{16}H_5NO_2$	= In
White indigo . . .	$C_{16}H_6NO_2$	= In, H
Sulphindigotic acid . . .	$C_{16}H_5NO_2, S_2O_6$	= In, S_2O_6
Isatin	$C_{16}H_5NO_4$	= InO_2
Isatic acid	$C_{16}H_7NO_6$	= HO, InO_3
Isathyd	$C_{16}H_6NO_4$	= InO_2H
Indin	$C_{32}H_{10}N_2O_4$	= In_2
Hydrindin	$C_{32}H_{11}N_2O_4$	= In_2H

Indigo-blue or *indigotin* ($C_{16}H_5NO_2$), may be obtained in a very beautiful form by mixing commercial indigo with about half its weight of plaster of paris and sufficient water to make a thick cream; this is evenly spread over an iron plate so as to form a stratum about one-eighth of an inch in depth, and set aside to dry. A spirit or gas flame is then applied to the under surface of the plate when the indigo sublimes out from the mixture and condenses in brilliant little purplish-brown crystals, on that part of the plaster immediately over the source of heat. By gradually moving the lamp the indigo is sublimed in successive portions that readily admit of being removed by a spatula from the hard cement below. Indigo-blue thus produced is very beautiful, but not pure. To obtain it in the latter state, it is necessary to dissolve it in a dilute alkaline solution, and as indigo itself is not soluble in such a menstruum, it is brought into intimate contact with some substance that is capable of furnishing hydrogen to it, hydride of blue indigo being thus formed which is quite soluble. One of the best methods of accomplishing this is the following. Four parts of indigo in powder, four parts of grape sugar, and ten parts of a saturated solution of caustic soda, are placed in a flask of such a size that it will hold about twenty times the volume of the mixture. The vessel is now filled up with boiling alcohol, well stoppered, briskly agitated, and set aside. The liquid soon becomes clear, and is then poured out into shallow vessels and exposed to the air, when it rapidly absorbs oxygen and deposits crystals; these when washed, first with alcohol and then with hot water, form perfectly pure indigo blue.

Indigo-blue is a neutral body, tasteless and inodorous. It is insoluble in water, alcohol, ether, oils, dilute acids, or alkalies. It fuses and sublimes in purple-coloured vapours at about 550° Fahr.; at a higher temperature it is decomposed, hydrocyanate and carbonate of ammonia, aniline, and an empyreumatic oil being among the the volatile products, while much carbonaceous residue remains.

White Indigo, Indigogen, or (improperly) *Reduced Indigo* ($C_{16}H_6NO_2 = C_{16}H_5NO_2,H$) is a combination of hydrogen with indigo blue, and may be prepared by several processes: all of which, however, depend upon the deoxidising effect they have upon water, the hydrogen of that compound being thus furnished to the indigo. Grape sugar is such a deoxidising or hydrogenising agent, and if to the dilute alkaline solution (already referred to in the description of the method for obtaining pure indigo blue) there be added acetic acid, dirty white flocks of indigogen are precipitated. White indigo is insoluble in water, slightly soluble in alcohol and in ether, and when exposed to the air rapidly absorbs oxygen, forming water and indigo-blue.

The solubility of white indigo in a dilute alkaline solution, and the insolubility of blue indigo in a similar menstruum, are facts of great interest and importance, as on them depend the use of indigo in the arts of dyeing and calico-printing. The deoxidising agents, other than grape sugar, that are used for making the *reduced indigo vats*, are protosulphate of iron, protochloride of tin, orpiment, and decaying vegetable matter; lime sometimes replacing the alkali. For details of the preparation of some of these baths or vats, see CALICO-PRINTING and DYEING.

Sulphindigotic acid, or *Sulphindylic acid* $(In,S_2O_6 = C_{16}\genfrac{}{}{0pt}{}{H}{H_4}NO_2,S_2O_6)$. One equivalent of hydrogen in this compound is replaceable by an equivalent of metal, forming salts called *sulphindigotates* or *sulphindylates*. Sulphindigotic acid is formed by dissolving commercial indigo in six times its weight of fuming or Nordhausen sulphuric acid. The product is known as *Saxony blue*, and is extensively used in cloth dyeing; it contains another acid named *hyposulphindigotic acid*, and the greater part of the residue from its preparation consists of *sulphopurpuric* or *sulphophenicic acid* $(2C_{16}H_5NO_2,S_2O_6)$. By the decomposition of these sulphuric derivatives of indigo there are produced *sulphoviridic, sulphoflavic, sulphofulvic*, and *sulphorufic acids*: they have been but little studied.

Isatin $(C_{16}H_5NO_4)$, a substance obtained from indigo by the addition of two equivalents of oxygen.

$$\underbrace{C_{16}H_5NO_2}_{\text{Indigo-blue.}} + O_2 = \underbrace{C_{16}H_5NO_4}_{\text{Isatin.}}$$

In order to prepare it, powdered indigo is to be mixed in water with equal parts of sulphuric acid and bichromate of potash, the last being dissolved in 20 or 30 parts of water. The indigo dissolves, and at first without the extrication of any gaseous matter, but towards the end with the disengagement of carbonic acid gas, and the formation of a deep yellowish brown liquid, from which the isatin separates by evaporation, in crystals; these are purified by repeated crystallisations in water, and one and the last in alcohol. Nitric acid may be used in the place of chromic for oxidising the indigo, but if too concentrated, indigotic acid (nitrosalicylic acid) results.

The properties of isatin are:—It crystallises in prisms, which are of a yellowish red or deep aurora-red colour, possessing much splendour when deposited from an alcoholic solution; they are slightly soluble in cold water, but dissolve readily in boiling water and in alcohol; these solutions discolour the skin, and impart a disagreeable odour to it. The crystals are decomposed by heat, leaving a charcoal which it is difficult to incinerate; the caustic alkalis convert it into isatic acid. Fused with solid hydrate of potash it is decomposed, aniline being produced according to the following equation:—

$$\underbrace{C_{16}H_5NO_4}_{\text{Isatin.}} + 4(KO\,HO) = \underbrace{C_{12}H_7N}_{\text{Aniline.}} + 4(KO,CO_2) + H_2$$

Chlorine and Bromine derivatives of Isatin.—One or two atoms of hydrogen in isatin may be replaced by one or two atoms of chlorine or bromine, and the following compounds formed:—

Chlorisatin	$C_{16}\genfrac{}{}{0pt}{}{H_4}{Cl}NO_4$
Dichlorisatin	$C_{16}\genfrac{}{}{0pt}{}{H_3}{Cl_2}NO_4$
Bromisatin	$C_{16}\genfrac{}{}{0pt}{}{H_4}{Br}NO_4$
Dibromisatin	$C_{16}\genfrac{}{}{0pt}{}{H_3}{Br_2}NO_4$

These compounds greatly resemble isatin, both in appearance and in all their reactions. The chlorine derivatives are produced by the action of chlorine upon indigo, and separated by crystallisation from alcohol, chlorisatin being less soluble in that liquid than dichlorisatin. The bromine derivatives are obtained in a similar manner from indigo, using bromine instead of chlorine.

Isatic acid $(C_{16}H_7NO_6 = HO,C_{16}H_6NO_5)$. Isatin dissolves in potash with a deep purple colour, which becomes bright yellow by heat. The solution yields by evaporation a crystalline salt of potash, which is soluble in alcohol, and crystallises in small, hard, colourless prisms. When a solution of this salt is mixed with one of acetate of lead, a white precipitate is obtained, which, diffused in water and decomposed by hydrosulphuric acid, yields a colourless acid liquid, and this by spontaneous evaporation furnishes a white and scarcely crystalline powder, which is hydrated isatic acid.

The properties of isatic acid are as follow:—It is perfectly insoluble in cold water; but when heated in water, it is decomposed into isatin and water, the mixture becoming of a reddish yellow colour: the soluble isatates act in the same manner with the mineral acids; when they are added to it cold, no decomposition is apparent; but as soon as heat is applied, the mixture becomes yellow, and deposits crystals of isatin.

Isatate of potash gives a white precipitate with barytic salts, soluble in boiling water; with the salts of silver it gives a white precipitate, which dissolves when heated in the mixture, a certain portion of the silver salt being reduced to the metallic state; the boiling solution of isatate of silver deposits crystals which are partly in laminæ and partly granular. The general formula of these *isatates* is $(C_{16}H_6MNO_6 = MO,C_{16}H_6NO_5)$.

Chlorine and Bromine derivatives of Isatic Acid.—These are—

Chlorisatic acid	$C_{16}H_6ClNO_6$
Dichlorisatic acid	$C_{16}H_5Cl_2NO_6$
Bromisatic acid	$C_{16}H_6BrNO_6$
Dibromisatic acid	$C_{16}H_5Br_2NO_6$

They are respectively produced by the action of potash upon chlorisatin, dichlorisatin, bromisatin, and dibromisatin, the potash salt of the acids being thus formed, and this, by double decomposition with the soluble salts of other bases, furnishes the several metallic derivatives of these acids.

Ammoniacal Derivatives of Isatin.—Ammonia acts upon isatin, giving rise to bodies that differ from each, according as the circumstances differ under which they are brought into contact. They all contain the elements of isatin, plus ammonia (NH_3) and minus water (HO). Their relations to each other are best shown by formulating them upon the ammonia type, or upon the hydrated oxide of ammonium type, as follows, in which blue indigo—that is, the radical *indyl* $(C_{16}H_5NO_2)$—is represented by the signs (InIn or In_2).

Imesatin	$C_{16}H_6N_2O_2 = N\begin{cases}In\\In\\H\end{cases}$
Imasatin	$C_{32}H_{11}N_3O_6 = \left.\begin{matrix}NIn_4O\\H\ O\end{matrix}\right\}$
Isamic acid	$C_{32}H_{13}N_3O_8 = \left.\begin{matrix}NIn_2H_2O\\H\ O\end{matrix}\right\}\ \left.\begin{matrix}InO\\InO\end{matrix}\right\}$
Isamide	$C_{32}H_{14}N_4O_6 = \left.\begin{matrix}NIn_2H_2O\\NIn_2H_2O\end{matrix}\right\}$
Isatimide	$C_{48}H_{17}N_5O_8 = \left.\begin{matrix}NIn_4O\\NIn_2H_2O\end{matrix}\right\}$

Each of the chlorine and bromine derivatives of isatin gives rise to a similar class of bodies, in each of which, of course, isatin is replaced by the chlor or brom derivative.

Imesatin is obtained in colourless prisms on passing a current of dry ammoniacal gas through a solution of isatin in absolute alcohol. *Imasatin* is produced when a solution of isatin in ammonia is maintained for a short time at the boiling point. It crystallises in lamellar grains. *Isamic*, called also *imasatic* and *rubendinic acid*, crystallises out in beautiful plates from an alcoholic solution of isamate of ammonia, to which hydrochloric acid has been added. Isamate of ammonia results from the metamorphosis of isatate of ammonia when a solution of the latter salt is evaporated to the consistence of a syrup. Bromine energetically attacks isamic acid, producing a yellow body termed *indelibrome*. *Isamide*, or *amasatin*, is formed when isamate of ammonia is strongly dried. *Isatimide* is a crystalline yellow powder formed during the preparation of imesatin, but is more soluble in the alcoholic ammonia, and therefore crystallises out subsequently to the imesatin. There appear, also, to be produced at the same time, *isatilime* $(C_{48}H_{16}N_4O_{10})$, containing three atoms of isatin, plus one of ammonia, minus two of water; and *amisatin* $(C_{96}H_{39}N_{11}O_{18})$, represented by six atoms of isatin, plus five of ammonia, minus six of water.

Isathyd $(C_{16}H_6NO_4 = C_{16}H_5NO_4, H)$.—This body may be viewed as the hydride of isatin, bearing the same relation to that body that white indigo does to blue. It is best prepared by placing isatin in a flask with zinc and dilute sulphuric acid. It is a grayish crystalline powder, insoluble in water and sparingly so in alcohol or ether. On passing a current of sulphuretted hydrogen through the alcoholic solution, *bisulphysathyd* $(C_{16}H_6NO_2S_2)$ is formed, a body in which two atoms of sulphur replace two of the oxygen in isathyd. On adding solution of potash drop by drop to an alcoholic solution of bisulphisathyd, one atom of sulphur is substituted by one of oxygen, and *sulphisathyd* is produced. By the action of hydridising agents upon the chlorine and bromine derivatives, corresponding *chlor* and *brom isathyds* are obtained.

Isatane $(C_{32}H_{12}N_2O_6)$ is a white powder, formed when bisulphisathyd is boiled with bisulphite of ammonia. It contains the elements of two molecules of isathyd, less two atoms of oxygen.

Indin is prepared by the action of potash on sulphisathyd, the alkali being subsequently removed by hydrochloric acid. It is pulverulent, of a very fine deep rose-red colour, insoluble in water, and slightly soluble in alcohol and ether. When heated, it begins to swell as soon as it melts. It yields a substance which crystallises in needles, and much charcoal remains. Boiling nitric acid decomposes it, altering its colour slightly, red vapours are formed, and *nitrindin* $(C_{32}H_9(NO_4)N_2O_4)$ is produced. If the ebullition be continued, the new product is also decomposed, and disappears. Sulphuric acid dissolves indin, assuming a red colour, and water precipitates it from solution unaltered; bromine colours it violet. Ammonia has no action on indin, but potash attacks it under certain circumstances. It is polymeric with blue indigo, and its probable composition is $(C_{32}H_{10}N_2O_4)$.

Indinic Acid is formed in combination with potash, yielding black crystals, by the continued action of the alkali upon indin; the indinate of potash is readily decomposed by water, and still more easily by acids; alcohol dissolves a little of it, but by long washing decomposes it. In the air it becomes of a light rose colour. Its composition appears to be ($C_{32}H_9KN_2O_4$).

Chlorine and Bromine Derivatives of Indin are produced by the action of heat on the corresponding derivatives of isathyd.

Hydrindin ($C_{64}H_{22}N_4O_8 + 2Aq.$) appears to contain the elements of indin plus hydrogen. It occurs in small white prismatic crystals, and is prepared by acting upon indin with an alcoholic solution of potash. The re-action also gives rise to *flavindin*, a body forming pale yellow acicular crystals.

INDIGO-BLUE. [INDIGO.]

INDIGO-WHITE. [INDIGO.]

INDIGOGENE. [INDIGO.]

INDIGOTIC ACID. [INDIGO.]

INDIGOTIC GROUP. According to Gerhard's system of classification of organic compounds, this group, belonging to the BENZOIC SERIES, consists of a number of bodies derived exclusively from indigo, under which the individual members of this group will be found described. Indigotic compounds possess a certain relation to salicylic, kinonic, and phenylic compounds. Thus salicylic acid, nitrosalicylic acid, perchlorokinonpicric acid, and aniline, can be obtained from indigotic compounds; but when once thus broken up, no indigotic body has yet been reproduced from these derivatives.

INDIGOTIN. [INDIGO.]

INDIN. [INDIGO.]

INDINIC ACID. [INDIGO.]

INDUCEMENT. [PLEADING.]

INDUCTION (ἐπαγωγή), as defined by Archbishop Whately, is "a kind of argument which infers respecting a whole class what has been ascertained respecting one or more individuals of that class." According to Sir William Hamilton the word has been employed to designate three very different operations:—1. The objective process of investigating particular facts, as preparatory to Induction, which he observes is manifestly not a process of reasoning of any kind; 2. A material illation of a universal from a singular, as warranted either by the general analogy of nature or the special presumptions afforded by the object matter of any real science; 3. A formal illation of a universal from the individual, as legitimated solely by the laws of thought and abstracted from the conditions of any particular matter. The second of these operations is the inductive method of Bacon, which proceeds by means of rejections and conclusions, so as to arrive at those axioms or general laws from which we may infer by way of synthesis other particulars unknown to us, and perhaps placed beyond reach of direct examination. ('Nov. Org.,' 'Aph.,' c. iii., c. v.) Aristotle's definition coincides with the third, and induction "is an inference drawn from all particulars." ('Prior Analy.,' ii., c. xxiii.) The second and third processes are improperly confounded by most writers on logic, and treated as one simple and purely logical operation. But the second is not a logical process at all; since the conclusion is not necessarily inferrible from the premise, for the *some* of the antecedent does not necessarily legitimate the *all* of the conclusion, notwithstanding that the procedure may be warranted by the material problem of the science, or the fundamental principles of the human understanding. The third alone is properly an induction of logic; for logic does not consider things, but the general forms of thought under which the mind conceives them; and the logical inference is not determined by any relation of causality between the premise and conclusion, but by the subjective relation of reason and consequence as involved in the thought. The inductive process is exactly the reverse of the deductive; for while the latter proceeds from the whole to the part, the former ascends from the part to the whole: since it is only under the character of a constituted or containing whole, or as a constituent and contained part, that anything can become the term of logical argumentation. Of these two processes, Sir William Hamilton gives the following figures:—

Induction.	Deduction.
X Y Z are A.	B is A.
X Y Z are whole B.	X Y Z are under B.
∴ whole B is A.	∴ X Y Z are A.
or,	or,
A contains X Y Z.	A contains B.
X Y Z contains B.	B contains X Y Z.
∴ A contains B.	∴ A contains X Y Z.

This confusion of material and logical induction led Gillies and others to insist on the sameness of the Baconian and Aristotelian induction; while Campbell and Dugald Stewart, who totally mistook the value of all logical inference, yet rightly maintained their difference.

By Aristotle, induction and deduction are viewed as in certain respects similar in form; but in others as diametrically opposed, the latter being an analysis of the whole into its parts, by descending from the more general to the more particular; but the former descends by a synthetical process from the parts to the whole. The logicians, who misapprehended the nature of induction, reduced it to a deductive syllogism of the third form, and thereby overthrew the validity of all deduction itself, since the latter is only possible by means of the former, which legitimates the proposition from which its reasoning proceeds.

Again, the Aristotelian induction was drawn from all the particulars, whereas the confusion which Sir W. Hamilton has pointed out gave rise to a division of the inductive process into perfect and imperfect, according as the enumeration of particulars is complete or incomplete. The latter gives only a probable result, whereas the necessity of the conclusion is essential to all logical inference, as its demonstrative stringency depends upon the form of the illation, and not upon the truth of the premises. It is proper to add, that no one ever knew the distinction between the imperfect and perfect forms of the conclusion better than Aristotle himself.

INDUCTION (Mathematics). The method of induction, in the sense in which the word is used in natural philosophy, is not known in pure mathematics. There certainly are instances in which a general proposition is proved by a collection of the demonstrations of different cases, which may remind the investigator of the inductive process, or the collection of the general from the particular. Such instances however must not be taken as permanent, for it usually happens that a general demonstration is discovered as soon as attention is turned to the subject.

There is however one particular method of proceeding which is extremely common in mathematical reasoning, and to which we propose to give the name of *successive induction*. It has the character of induction as defined by the logicians, because it is really the collection of a general truth from a demonstration which implies the examination of every particular case; but it adds to the necessary character of induction that each case depends upon one or more of those which precede. Substituting demonstration for observation, the mathematical process is truly inductive. A couple of instances of the method will enable the mathematical reader to recognise a mode of investigation with which he is already familiar.

Example 1.—The sum of any number of successive odd numbers, beginning from unity, is a square number, namely, the square of half the even number which follows the last odd number. Let this proposition be true in any one single instance; that is, n being some whole number, let 1, 3, 5, ... up to $2n+1$ put together give $(n+1)^2$. Then the next odd number being $2n+3$, the sum of all the odd numbers up to $2n+3$ will be $(n+1)^2+2n+3$, or n^2+4n+4, or $(n+2)^2$. But $n+2$ is the half of the even number next following $2n+3$: consequently, if the proposition be true of any one set of odd numbers, it is true of one more. But it is true of the first odd number 1, for this is the square of half the even number next following. Consequently, being true of 1, it is true of $1+3$; being true of $1+3$, it is true of $1+3+5$; being true of $1+3+5$, it is true of $1+3+5+7$, and so on *ad infinitum*.

Example 2.—The formula x^n-a^n, n being a whole number, is always algebraically divisible by $x-a$.

$$\begin{aligned} x^n-a^n &= x^n-a^{n-1}x+a^{n-1}x-a^n \\ &= x\,(x^{n-1}-a^{n-1})+a^{n-1}\,(x-a) \end{aligned}$$

In this last expression the second term $a^{n-1}(x-a)$ is obviously divisible by $x-a$: if then $x^{n-1}-a^{n-1}$ be divisible by $x-a$, the whole of the second side of the last equation will be divisible by $x-a$, and therefore x^n-a^n will be divisible by $x-a$. If then any one of the succession

$$x-a,\ x^2-a^2,\ x^3-a^3,\ x^4-a^4,\ \&c.$$

be divisible by $x-a$, so is the next. But this is obviously true of the first, therefore it is true of the second; being true of the second, it is true of the third; and so on, *ad infinitum*.

There are cases in which the successive induction only brings any term within the general rule, when two, three, or more of the terms immediately preceding are brought within it. Thus, in the application of this method to the deduction of the well-known consequence of

$$x+\frac{1}{x}=2\cos\theta,\ \text{namely,}\ x^n+\frac{1}{x^n}=2\cos.\,n\,\theta,$$

it can only be shown that any one case of this theorem is true, by showing that the preceding two cases are true; thus its truth, when $n=5$ and $n=6$, makes it necessarily follow when $n=7$. In this case the two first instances must be established (when $n=1$ by hypothesis, and when $n=2$ by independent demonstration), which two establish the third, the second and third establish the fourth, and so on.

An instance of mathematical induction occurs in many equations of differences, in every recurring series, &c.

INDUCTION, ELECTRICAL. [ELECTRICITY, COMMON; GALVANISM; MAGNETO-ELECTRICITY.]

INDUCTION. [BENEFICE.]

INDULGENCE is a power claimed by the Roman Catholic church, of granting to contrite and confessed sinners remission of the penalty, or part of the penalty, which they ought to suffer here or hereafter in expiation of their sins. The indulgence does not remit the guilt, "culpa," nor the eternal punishment awarded to the impenitent sinner, but only the temporal penalty which the repentant sinner, after having duly confessed his sins and received absolution, has still to undergo, either in this world or in purgatory, according to the belief of Roman Catholics. [Confession.] In the early ages of the church repentant sinners after confession had to undergo public punishment, often very severe, in proportion to their offences; such punishments, however, were occasionally mitigated by the "indulgence" of the bishops, who, in particular cases, abridged the austerities enjoined by the canons, or commuted them for works of charity and pious exercises. Such was the origin of indulgences. (Maldonat, 'De Indulgentiis; Bibliothèque Sacrée,' par les Pères Richard et Giraud, article 'Indulgence;' Lingard, 'History of England,' vol. iv.)

Several of the early fathers of the church, such as St. Cyprian ('De Lapsis') and Tertullianus ('De Pudicitia'), complained of the abuse of this practice in their time, and especially that simple priests presumed to grant indulgences, which was the exclusive privilege of bishops, and that bishops themselves granted them with too much facility. The canonical or ceremonial penalties becoming in course of time disused, together with the practice of public confession, the indulgences which continued to be granted afterwards were understood to remit that part of the penance to be undergone in purgatory which was equivalent to the canonical penalty which would have been awarded by the early church. (Maldonat.) "The faith of Catholics," says Maimbourg ('Histoire du Luthéranisme,' vol. i.), "has always been that the Son of God has conferred on his church the power of relieving the penitent sinner not only from the bonds of his sin by the merits of Christ's passion applied to him in the sacrament of confession, but also from the punishment which he would suffer, either in this world or the next, as a satisfaction to the divine justice for offences committed after baptism. Hence St. Paul, at the request of the Corinthians, remitted to the incestuous man whom he had excommunicated, the remnant of the penalty incurred for the crime; hence the bishops of the earliest ages gave peace to apostates, and reconciled them to the church by abridging the time of the criminal penance through the intercession of martyrs, and in virtue of their sufferings, joined to those of the Saviour of the world, who rendered them precious in the sight of God." The 'Bibliothèque Sacrée,' above quoted, contains a most elaborate article on the subject of indulgences, divided into eight sections, namely—1. On the name and nature of indulgences. 2. On the various sorts of indulgences. 3. On their virtues and effects. 4. On their truth and foundation. 5. On the causes of indulgences. 6. On the subjects or persons to whom indulgences are applied. 7. On the conditions and dispositions required in order to obtain the benefit of the indulgences. 8. On the abuse of indulgences. We may observe on this last point that indulgences are granted in some cases to those who give money for the building of churches and other pious purposes; but that the sale of or traffic in indulgences has been severely reprobated by many councils, and that the bulls of indulgences granted by the Pope contain the clause that "if any thing be given as the price of this indulgence, the indulgence itself becomes null." The sale of indulgences, however, has on many occasions been connived at by the higher authorities in the Romish church, and, as is well known, it was the indignation excited by an act of this kind which first aroused the anti-papal spirit in Luther, and led eventually to the Reformation.

INDUS (the Indian), a constellation of Bayer, situated between Sagittarius and the South Pole.

Character.	No. in Catalogue of Lacaille.	No. in Catalogue of British Association.	Magnitude.
α	1676	7096	3
β	1691	7228	4
γ	1731	7428	5
δ	1764	7633	5

INEQUALITY. (Astronomy.) For convenience, the average motion of a planet or satellite, supposed to be made in a circle which has the average distance of the body from the sun or primary for its radius, is the first object of calculation when the place of the body at some future time is to be predicted. All the alterations which are rendered necessary by the unequal motion of the planet are called inequalities. [Gravitation; Lunar Theory; Planetary Theory, &c.]

INERTIA. This word means something equivalent to the modern English sense of *inactivity*, or rather of *incapability*, and expresses that property of matter by which it does not change its own state of rest or motion, but requires for that purpose the action of some external cause, to the magnitude of which the change is in proportion. Previous to some remarks upon the use of this word, we shall give at length the third definition of Newton's 'Principia,' from which the common usage of it is derived. "The *vis insita*, or innate force of matter, is a power of resisting by which every body, as much as in it lies, endeavours to persevere in its present state, whether it be of rest or of moving uniformly forward in a straight line. This force is ever proportional to the body whose force it is; and differs nothing from the inactivity of the mass, but in our manner of conceiving it. A body, from the inactivity of matter, is not without difficulty put out of its state of rest or motion. Upon which account this *vis insita* may, by a most significant name, be called *vis inertiæ*, or force of inactivity. But a body exerts this force only when another force, impressed upon it, endeavours to change its condition," &c.

We could wish that the use of this word were entirely exploded, and for the following reason. When a term is proposed to stand for a property, mode of being, or condition of existence, about which we know nothing except that certain phenomena always occur under certain circumstances, such a proposition may be listened to, on condition that there is one distinct phenomenon or class of phenomena, which wants a distinctive name, and also on condition that the word is to be used in a purely characteristic, and not in a doctrinal or explanatory sense. Thus the word *impenetrability* [Impenetrability], though likely to cause misconception, as pointed out in the article cited, is nevertheless a good word to those who know how to use it, and a necessary word to those who desire to describe and reason on our knowledge of matter. It conveys to the mind, by one act of separation or abstraction, the notion of a cause for a phenomenon which might be conceived to exist independent of the other properties of matter. We can imagine impenetrable space, not endowed with mobility, colour, or any other accident of matter. But with the word inertia as used by Newton, we do not describe any quality of matter, but supply a term of causation for matter itself, so far as those properties are concerned which are studied in mechanics. What is the *matter* of a work on pure statics or dynamics? That which obeys certain three laws of motion, or presents phenomena which are of a certain threefold description. What word, according to Newton, should be used as a term of causation to remind us that the first law of motion arises from something inherent in the constitution of matter? The inertia, or vis inertiæ. What for the second law? The inertia. What for the third law? Still the inertia. Consequently, this inertia is literally nothing but an expression of the incapability of matter to obey any other laws except those which it really does obey; and the policy of admitting such a term is not merely a question of mechanics. Need we accompany every fundamental term of every science by another, which merely expresses that there must be some reason why the thing signified has the collection of properties which it is found to possess, and not any other? We think the answer must be in the negative, in which case the word matter itself may be substituted for inert substance, the two phrases being perfectly interchangeable in every work on mechanics. [Motion, Laws of.]

If the word inertia be admitted at all as one of distinction, it must be to separate the object of geometry from that of mechanics. In the former we consider space only, that is, bounded portions of space: in the latter we suppose this bounded space to have inertia. But the distinction is quite sufficiently made without the introduction of a synonymic. In geometry we consider space without reference to the question, whether the space be vacuum or matter; in mechanics we consider matter.

Thus much for the use of inertia in a scientific sense: in many popular writings we find it applied as a sort of explanation of the properties of matter, which are so and so *because* matter has inertia. Since this vicious application of words is not by any means confined to the case before us, it is needless to enlarge upon it.

There is one use of the word inertia which is convenient and harmless, namely, as part of the phrase MOMENT OF INERTIA. If we imagine a material system which admits of revolution about a fixed axis, it is obvious that the more closely the matter of which it is formed is collected about the axis the less resistance will be offered to the production of rotatory motion. The law of this resistance will be explained in the article alluded to.

INFAMY (from the Roman Infamia) in English law is not easily defined. Certain offences were formerly considered of so heinous a nature that conviction and judgment for them rendered a man infamous and incompetent to be a witness. But the endurance of the punishment, or reversal of the judgment, restored a man's competency as a witness. The 9 Geo. IV. c. 32, § 3, enacts, that when a man convicted of a felony shall have undergone the legal punishment for it, the effect shall be the same as a pardon under the Great Seal; and (§ 4) no misdemeanour, except perjury or subornation of perjury, shall render a man an incompetent witness after he has undergone his punishment. The 6 & 7 Vict. c. 85 (introduced into the House of Lords by Lord Denman, and carried into law after great discussion) was the Act by which many of the old abuses in our rules of evidence were remedied, and the views of the advocates of reform were carried out. This Act, which is entitled 'An Act for Improving the Law of Evidence,' after remarking on the obstructions in the way of eliciting truth in courts of justice owing to incapacities created by the existing law, and the desirability that those who have to decide on the facts in issue should exercise their judgment on the credit of the witnesses, enacts that no person offered as a witness is to be excluded on account of incapacity from crime or interest from giving evidence, either in person or by deposition, on the trial of any issued joined, &c., but that every such person may be admitted to give evidence on oath or affirmation, notwithstanding such person may have been convicted of any crime or offence. [Evidence.]

Certain offences enumerated in the 7 & 8 Geo. IV. c. 29, § 9, are infamous crimes, with reference to the provisions of that Act. Though infamy does not disqualify a man from being a witness, it may be urged as an argument against his credibility, for, as an American judge has said

"It is perfectly safe and most conducive to the purposes of justice, to trust the jury with a full knowledge of the standing of a witness into whose character an inquiry is made. It will not thence follow that from minor vices they will draw the conclusion in every instance that his oath must be discredited, but only be put on their guard to scrutinise his statements more strictly, while in cases of vile reputation in other respects they would be warranted in disbelieving him, though he had never been called so often to the book as to fix upon him the reputation of a liar when on oath." (Hume *v.* Scott, 3 A. K. Marshall, 261.) As to this branch of the English law of evidence, see Taylor on Evidence, vol. ii. §§ 132—1328; and Best on Evidence, 2nd edit., pp. 184—187.

The only satisfactory definition of infamy would be a permanent legal incapacity to which a man is subjected in consequence of a conviction and judgment for an offence, and which is not removed by suffering the punishment for the offence. By 2 Geo. II. c. 24, § 6, persons who are legally convicted of perjury or subornation of perjury, or of taking and asking any bribe, are for ever incapacitated from voting at the election of members of parliament; and by 17 & 18 Vict. c. 102, s. 6, it is enacted that after a conviction of any person, if a voter, in a court of law for bribery or undue influence, or after judgment in a penal action for bribery, treating, or undue influence, the revising barrister is to expunge the offender's name from the list of voters, to disallow it when sought to be inserted there, and (in either of the last two events) to place it in a list to be entitled 'The List of Persons Disqualified for Bribery, Treating, or Undue Influence.' Such persons are therefore infamous: they labour under infamy, and have lost part of their political rights.

The Roman term Infamia is the origin of our term infamy. Infamia followed in some cases upon condemnation for certain offences in a judicium publicum; and in other cases it was a direct consequence of an act, as soon as such act became notorious. Among the cases in which Infamia followed upon condemnation, were, insolvency, when a man's goods were taken possession of by his creditors in legal form and sold; the actio furti, and vi bonorum raptorum: actio fiduciæ, pro socio, tutelae, &c. In all these cases a judicial sentence, or something analogous to it, was necessary, before infamia could attach to a person. Among the cases in which infamia followed as an immediate consequence of acts which were notorious are the following: the case of a woman caught in adultery, of a man being at the same time in the relation of a double marriage, of prostitution in the case of a woman, or of a man or woman gaining a living by aiding in prostitution.

Savigny, in his review of the different circumstances which led to the penalty of infamy among the Romans, points out two elementary principles common to them all. First, that infamy always attached to the *personal* act of the individual declared infamous; secondly, that it was in consequence of his *act* and not owing to the *nature of the penalty*, that the offender was adjudged to be infamous. (D. 3, 2, 22.)

The consequence of Infamia was incapacity to obtain the honours of the state, and probably the loss of the suffrage also; and it was perpetual. The infamis was still a citizen (civis), but he had lost his political rights. The infamous man was also under some disabilities as to his so-called private rights. He was limited by the Prætor's edict in his capacity to postulate (that is, take the initial measures for asserting or defending his rights in legal form), to act as the attorney of another in such cases, to be a witness, and to contract marriage.

The rules of the Roman law as to Infamia are chiefly contained in the 'Digest,' iii. tit. 1 and 2, and Code, ii. tit. 12. In addition to these texts contained in the Corpus Juris Civilis, the reader is referred to the old fragmentary Roman law called the 'Tabula Heracliensis,' published at Rome about the year 709, under the name of the Lex Julia Municipalis, which will be found to bear upon the authorities above referred to.

(See Savigny, *System des heut. Röm. Rechts*, ii. § 76–83; Becker, *Handbuch der Röm. Alterthumer*, ii. 121; Puchta, *Institutionem*, ii. 441; Muhlenbruch, *Doctrina Pandectarum*, vol. ii. §§ 189 *et seq.*)

INFANT, a person under the age of twenty-one, whose acts are in many cases either void or voidable. As a general rule, an infant cannot make any binding contract, though to this there are some exceptions: thus an infant may bind himself to pay for his necessary meat, drink, apparel, physic, and such other necessaries, and likewise for his good teaching and instruction. But where an infant is living in his father's house and under his care, he is not liable even for necessaries. Necessaries for an infant's wife are necessaries for him. Infants are also incapacitated from making a will.

It should also be observed, that an infant, how young soever he may be, and even a child in the womb, or, as it is technically expressed, *en ventre sa mere*, may be appointed an executor: but the statute 38 Geo. III., c. 87, disqualifies an infant who is appointed *sole* executor from exercising the office during his minority; and administration with the will annexed must be granted to the infant's guardian, or to some other person, until the infant is of full age.

An infant en ventre sa mere is supposed in law, for most purposes, to be a person in being. Thus he may take an estate, and the taking away of his life may amount to homicide.

INFANT HEIR. [HEIR.]

INFANT SCHOOLS. [SCHOOLS.]

INFANT WITNESSES. [AGE.]

INFANTICIDE. The practice of putting infants to death has existed from the remotest periods on record, though the motives for the act have somewhat varied. In some at least of the states of Greece the destruction of those who were born weak or deformed was either commanded or allowed. In Rome children were exposed or put to death, not only with the view of removing those who might throughout life have remained a burden to their friends and useless to the state, but to prevent the too rapid increase of the population. The propagation of Christianity first checked the practice; and in A.D. 315, Constantine the Great provided for the maintenance of the offspring of those who were themselves destitute. Infanticide prevailed however to a slight extent till the reign of Valentinian, who "included such murders in the letter and spirit of the Cornelian Law." (Gibbon, 'Decline and Fall.') Among the contemporary barbarous nations, the same motive, and the sacrifices required for their deities, induced the same crime.

In modern times, the practice, though it is not anywhere sanctioned or commanded by law, is yet permitted in many countries. In China a large proportion of the female population are put to death as soon as they are born. Among the Hindus it was practised to a very great extent, till the Marquis of Wellesley, when appointed Governor-General of India, used every possible exertion to put a stop to it. By the perseverance of Major Walker and others his endeavours were successful, though unhappily for only a short time, for Bishop Heber tells us that "since that time things have gone on very much in the old train, and the answer made by the chiefs to any remonstrances of the British officers is, 'Pay our daughters' marriage portions, and they shall live.'" ('Narrative of a Journey in Upper India,' and 'Hindu Infanticide,' by E. Moor, F.R.S., 1811; including Walker's 'Report.') On the island of Ceylon, Heber also remarks that in 1821 "the number of males exceeded that of females by 20,000; in one district there were to every hundred men only fifty-five women, and in those parts where the numbers were equal the population was almost exclusively Mussulman." Here also, as in Hindustan, the difficulty and expense of educating female children, and the small probability of their marrying without some dowry, while a single life is deemed disgraceful, are the motives leading to the perpetration of the crime. Amongst the Mohammedans the practice is not discountenanced, though the necessity for it is greatly lessened by the habit of producing abortion, which almost universally prevails. In the numerous islands of the Pacific, infanticide is practised to such an extent, that some of them have at times, when pestilence has contributed its influence, been nearly depopulated. When Cook visited Otaheite, he found its population to be upwards of 200,000; but in the early part of this century it was reduced to between 5000 and 6000, and this principally from the practice of murdering their offspring. Mr. Ellis ('Polynesian Researches') says that he does "not recollect having met with a female in the island, during the whole period of his residence there, who had been a mother, while idolatry prevailed, who had not imbrued her hands in the blood of her offspring." We have similar accounts from nearly all the northern parts of America, from Hudson's Bay, Labrador, Mexico, &c.; but it is most gratifying that in all, one of the first and greatest blessings which have followed the introduction of Christianity and civilisation has been the decrease or complete cessation of this abominable custom.

In more civilised lands, although infanticide is regarded with the deepest abhorrence, and is visited with the extremest severity of the law, the expense and trouble of maintenance, and the fear of shame and loss of reputation, are motives sufficiently powerful for the occasional perpetration of the crime.

It is one of the most difficult questions of medical jurisprudence to discover and establish the murder of a child lately born. The chief points for decision are, 1st, whether the infant, the subject of inquiry, was born dead or alive; and 2nd, whether its death was the result of violence or of natural causes.

To establish the former point it is necessary to prove first that the infant was not born before the end of the sixth month after conception, because before that time a fœtus cannot be deemed capable of maintaining an independent existence, or to be what is called *viable*. This being proved from the size and form of the child, the decision whether it were born alive or not must generally rest on the condition of the lungs and heart, in which certain remarkable changes are produced as soon as respiration in the air has commenced. In the fœtus in utero and in the still-born child the lungs are of a dark purplish or chocolate colour, nearly like that of the liver; they are small, and occupy only a small part of the cavity of the chest, in which they lie close against the spine; they have a firm solid consistence, like liver, and their edges are sharply lobed. In the child which has breathed the lungs are of a florid red or rosy hue; they nearly fill the chest, and are found on opening it to be almost in contact with its front wall: their substance is soft, spongy, and light—they crepitate or crackle when pressed, frothy fluid may be squeezed out from an abundance of minute cellules, and their edges and lobes, instead of being sharp, are smoothly rounded off. If the child has breathed fully for some minutes after birth, these characters will generally be sufficient to decide the point in question, but in more difficult cases the weight of the lungs and their specific gravity require to be examined. At the same time that the air enters the lungs in respiration, a much larger quantity of blood is sent to them from the heart than had before circulated through them, and they therefore become considerably heavier. Ploucquet has on this ground proposed what is called the Static Lung Test, which is applied by comparing the absolute weight of the lungs with that of the whole body. By subsequent observers it has been determined that the weight of the lungs of still-born children is somewhat less than $\frac{1}{70}$ of that of the whole body, and that of the lungs of children that have breathed, rather more than $\frac{1}{35}$. This difference, though not sufficient to make this test by itself decisive, is yet of much importance as an addition to other evidence, and is especially to be considered in connection with the hydrostatic test, which is founded on the specific gravity of the lungs. As the air and blood enter the lungs at the same time, their relative weight is diminished, although their absolute weight is increased; so that a portion of the lung of a still-born child is heavier than a portion of the same size from a child which has breathed. The former is heavier, the latter lighter than water; and hence a simple test is obtained by observing whether the lungs of the infant under examination will float or sink when thrown into a vessel of water. When carefully employed, these two tests cannot fail to decide whether the child has breathed or not, but there are circumstances which may in some degree obscure the evidence to be drawn from them. First, there are those circumstances which may cause the lungs of a child which has never breathed to float in water. A certain degree of putrefaction may do this, by the quantity of gas which is generated in their tissue. This however cannot take place until the whole body of the infant is extremely putrid, for the lungs are amongst the organs which remain longest unaltered after death. Nor could a competent person fail to discover the difference between lungs rendered light by putrefaction and those which had breathed; the former present large bubbles of gas on their surface, which may be squeezed out by pressure under water, and when this has been done, the portion of lung to which they were attached will immediately sink. In some very rare cases emphysema of the lungs is produced during birth, but this also can at once be known by the air being contained in large bubbles, from which it may be pressed out. Lastly, the lungs may have been artificially inflated after death, but in this case the alteration of colour and volume, though produced in the same manner as in natural respiration, are only partial; some portions of the lungs are spongy and ruddy, but others are solid and livid. All the doubt that might arise from any of these circumstances may be removed by cutting up the lungs into small portions and squeezing each piece firmly under water: if natural respiration has been performed the smallest portion of lung, unless torn by the continued pressure into mere shreds, will continue to float; but in every other case the air may be so completely expelled that every portion will sink. In no case moreover, except where natural respiration has taken place, will the absolute weight of the lungs be increased; for in no other does the increased flow of blood from the heart take place.

On the other hand, there are very rare cases in which, though the child was born alive, the lungs will not float. They may be diseased, or the infant may have been too feeble to breathe completely, but in both these cases the same plan of cutting each lung into small pieces and testing each will remove all doubt, for there will be at least some portions into which the air has entered sufficiently to inflate them completely. The static and hydrostatic tests therefore, when carefully employed together, will prove whether the child have breathed, but they afford no evidence as to whether it was murdered or not. For it may have breathed during birth, and have died before it was completely born; or, on the other hand, it may have lived for a short time without breathing. These cases are however exceedingly rare, and their occurrence is so clearly indicated by the appearances found on the body, that they rarely embarrass the evidence that is given.

The signs of a child having lived after birth, which are to be found in the heart and other parts, afford no positive information unless life has continued for at least a day, and then the lungs alone will always suffice for decision. We need not here consider the evidence required to prove whether a child born alive was murdered, or died from natural causes, for it must be similar in all respects to that which is necessary in cases of homicide. [Homicide.]

Law relating to Infanticide.—If the result of the evidence be that the child was born alive, and that it was destroyed, the offence is murder, and punishable accordingly. [Murder.] If a woman be quick with child (that is, if she has felt the child move within her), it is a felony if she take, or any person administer to her, or use any means to procure abortion, and is punishable by penal servitude for life.

The murder of bastard children by the mother was considered as a crime so difficult to be proved, that the statute 21 James I., c. 27, made the concealment of the death of a bastard child absolute evidence that it had been murdered by the mother, except she could prove, by one witness at least, that it had been actually born dead. This cruel law was mitigated by the 43 George III., c. 58; and now, by the statute 9 George IV., c. 31, s. 14, the concealment of the body of a bastard child is declared to be a misdemeanour, and made punishable by imprisonment for any term not exceeding two years, with or without hard labour.

These are the regulations of the English law directly designed to prevent infanticide. There are however institutions in this country, as well as many other European countries, which have been founded with the view of restraining the commission of the crime, of which an account is given in the article Foundling Hospitals: but the history of these establishments shows that though they may have rendered infanticide less frequent, they have by no means tended to preserve the lives of illegitimate children; for in all of them, except the London Foundling Hospital, which is a comparatively wealthy establishment, their records show an astonishing amount of mortality, in some cases as high as eleven-thirteenths.

INFANTRY is a name given to the soldiers who serve on foot. It is immediately derived from the Italian word *fante*, which, though in strictness denoting a child, is in general applied to any young person. From the latter word comes *fantaccino*, and this is the origin of *fantassin*, a name which was once so commonly applied to a foot-soldier. During the time that the feudal polity was in vigour the numerous dependants of the nobility served in the wars, for the most part, on foot; and being called children, because they were so considered with respect to their patron lords, or to the towns from whence they were drawn, the word infantry became at length the general name for that species of troops. Boccaccio, who wrote in the 14th century, designates by the word *fanteria* the men who marched on foot in rear of the cavalry.

Among the ancient nations of Europe the foot soldiers constituted the chief strength of the armies. In the best days of the Grecian and Roman states battles were mainly won by the force and discipline of the phalanges and legions, and the number of the infantry in the field far exceeded that of the cavalry. The cavalry were then, as at present, employed chiefly in protecting the wings of the army and in completing the victory which had been gained by the infantry. It may be remarked also that most of the writers on tactics, from Folard downwards, express a decided preference in favour of the infantry.

The French historians agree that the ancient Franks, when they left the forests of Germany, were accustomed to march and fight on foot; and they persevered in this practice even after they had obtained possession of the country of the Gauls, which abounded with horses. In this country also the greater part of the Anglo-Saxon forces consisted of infantry, the cavalry being formed of the thanes, or rich proprietors of the land: the infantry were divided into heavy and light armed troops; the former being provided with swords and spears and large oval shields, and the latter having only spears, clubs, or battle-axes.

But soon after the time of Charlemagne the institutions of chivalry began to be generally adopted in the kingdoms of Europe. These led to frequent and splendid exhibitions of martial exercises on horseback in presence of the sovereigns and assembled nobles; and the interest inspired by the achievements of the knights on those occasions was naturally followed by a high regard for that order of men. By degrees the cavalry, which was composed of persons possessing rank and property, and completely armed, acquired the reputation of being the principal arm in war; and the foot soldiers, ill armed and disciplined, were held in comparatively small estimation.

From the capitularies of the French kings of the second race it appears that the foot soldiers who served in the armies of France consisted of slaves and freed serfs: the latter were either peasants or artificers, who, for the benefit of the army, occasionally exercised their particular trades, as shoeing horses, forming intrenchments, &c.; and, in action, like the men of the inferior class, were employed as skirmishers or light-armed troops. Similarly the infantry of this country, for some time after the Conquest, consisted of the yeomanry, vassals and dependants of the feudal tenants; and occasionally foot soldiers were engaged by the kings, under indentures, to serve in the wars. The English troops at that time wore a plain iron helmet called a *bascinet*, and a linen doublet stuffed with wool or cotton; their arms were generally pikes, but frequently they had swords and battle-axes.

Under the third race of kings in France the possessors of fiefs were not compelled to furnish infantry for the armies; and it appears that this duty was then imposed on the towns. The troops thus raised were obliged to serve only in or near the towns to which they belonged; or, if they were marched to a considerable distance from thence, they received pay. In the reign of Philip Augustus this militia must have been very numerous; for in some districts it was formed into legions, and was commanded by persons of distinction. At the battle of Bovines (1214) the municipal militia formed the first line of the French army, but it was defeated by the German infantry which was more numerous, and even then of better quality, than that of France.

In 1448, Charles VII. instituted the militia denominated *Francs Archers*, which consisted of 16,000 foot soldiers armed with bows. But this body existed only about 40 years, when it was suppressed by Louis XI., who formed a standing army of 10,000 French infantry, to which were joined 6000 Swiss; and subsequently Charles VIII. added a large body of Lansquenets, or German infantry. The reputation of the native troops in France seems to have been then at a low ebb; for Brantôme, in his 'Discours des Colonels,' describes them as being mostly the refuse of society—men with matted hair and beards, who for their crimes had had their shoulders branded and their ears cut off. On the other hand the Swiss soldiers were inured to discipline; they were protected by defensive armour and formed into deep battalions, in which state they were able to render the shock of cavalry entirely unavailing. Large divisions of these troops accompanied the army of Charles VIII. into Italy, in 1494, where their good conduct and discipline greatly contributed to raise the reputation of the infantry to its ancient standard.

The superiority of this class of troops consists in their being able to act on ground where cavalry cannot move; and it is obvious that the latter must, at all times, have been nearly useless in the attack and defence of fortified castles or towns. Even when the cavalry were held in the highest estimation it was sometimes found convenient for the knights to dismount and act as infantry. Froissart relates that at the battle of Cressy the English troops were formed in three lines, consisting of men-at-arms who fought on foot and were flanked by archers. At Poitiers and Agincourt also the men-at-arms engaged in a similar manner.

The Spanish soldiery, probably from being almost constantly engaged in warfare with the Moors, had early acquired considerable reputation; and the gallantry of the troops on foot, in keeping the field after the cavalry had retired, has been supposed, though this opinion of the origin of the name is now rejected as fanciful, to have been commemorated by the designation of infantry, which was bestowed upon them, it is said, in consequence of their having been headed on that occasion by an Infanta of Spain. The great share which the Spanish forces had in the wars carried on both in Italy and Flanders during the reigns of Ferdinand, Charles V., and Philip II.; their steady discipline, and the success which resulted from the association of musketeers with pikemen in their battalions, caused the infantry of Spain to be considered, during many years, as the best in Europe. But the rivalry in arms between the Emperor Charles V. and Francis I. of France, and the connection of Henry VIII. of England with both, led, in the several states of those monarchs, to the adoption of the improvements which had been introduced by the Spaniards. It may be added that the practice of keeping up standing armies composed of men trained in the arts of war under a rigid system of discipline, together with the universal adoption of the musket, has now brought all the infantry of Europe to nearly the same degree of perfection.

In 1859 the English army numbered 86,983 infantry troops, exclusive of engineers and artillerymen, many of whom serve on foot: besides those serving in India, under the name of the East Indian Army.

INFECTION is the contamination of the atmosphere or other inert substances by the deleterious or offensive qualities of malaria, the matter of contagion, effluvia from putrid animal or vegetable substances, &c. Some of these are at once recognised by the smell, or by chemical analysis, but the presence of others is known only by the diseases which they produce. The same means however may be applied in many cases for preventing the injurious effects of both classes.

The most important and valuable method of disinfection is ventilation, and, whatever other may be added to it, this should never be neglected. The apartment, or whatever requires to be purified, should be exposed to a constant and free current of fresh air, till every trace of odour is completely expelled, or as long as any emanation is going on. The reputation of chlorine, acids, lime, charcoal, &c., as disinfectants, depends on their property of decomposing the offensive gases which are so often mixed in the atmosphere with the matter of infection, but it is questionable whether they have any influence on the infectious particles themselves. However as the emanations from putrid substances render the body peculiarly liable to the reception of infection, some of these means should be employed where any offensive smell is present. Fumigations with aromatic substances, as camphor, &c., are perfectly useless, only serving to conceal the smell, but having no influence either on it or the infectious particles. Perfect cleanliness is of the greatest importance; every portion of the room or house should be carefully and frequently washed with hot soap and water; clothes and everything removable should be immersed in hot water, and after being well washed should be exposed for a long time to the open air, or sprinkled with chloride of lime; the walls and ceilings should be whitewashed, and beds, bedding, &c., cleaned and exposed in the open air. Dr. Henry has rendered it probable by numerous experiments that the infectious qualities of substances which cannot be conveniently washed, as trunks, packages of valuable merchandise, &c., may be sufficiently destroyed by exposing them to a dry heat of 200° for not less than an hour.

The following are some of the agents which are employed for the purpose of destroying infectious matters of various kinds:—

Chlorine.—This gas has a great affinity for hydrogen gas [CHLORINE], and as the latter forms so conspicuous an element in infectious compounds, they are destroyed when exposed to the agency of chlorine. Chlorine is especially applicable where infectious substances exist in the atmosphere. It may be employed by generating it from the decomposition of common salt with peroxide of manganese and oil of vitriol, or by mixing red lead with dilute muriatic acid. These preparations however require caution, and the more common plan is to use the solutions of chlorinated lime or soda. These solutions may be applied to floors, and vessels may be rinsed out with them. They may be diluted and linen rinsed out in them.

Permanganates of soda and potash.—These substances are powerful oxidisers. Wherever animal and vegetable matters exist in a state of decomposition, they oxidise the hydrogen and nitrogen, forming nitric acid and water. They are sold under the name of "Condy's disinfecting fluid," and are exceedingly useful where solid or liquid infectious matters have to be dealt with. They speedily render the matter of cesspools, drains, and sewers, perfectly innocuous. They may be also employed for the purification of water, and by their action on organic matters, can be employed as a test for the purity of water. The disinfecting quality of permanganic acid depends on the presence of ozone in this acid, which is readily given up to the organic matters with which it comes in contact.

Chloride of zinc.—This substance has the power of arresting change in decomposing animal and vegetable substances, and may be employed for this purpose, but it does not act so perfectly as the foregoing substances.

Perchloride of iron.—The salts of iron have all a great power of combining with organic matters, and arresting the progress of decomposition, and also of destroying infectious matters. It is one of the cheapest substances that can be employed for disinfection on a large scale, and is the compound recommended to the Metropolitan Board of Works for deodorising the Thames.

Sulphurous acid.—This acid is formed by leaving sulphur in the open air, and acts as a disinfectant by combining with oxygen, and becoming converted into sulphuric acid. It cannot however be used in rooms where persons are breathing on account of its suffocative action.

Salts of various kinds arrest decomposition, as nitrate of potass, chloride of sodium, sulphate of zinc, &c., but are not to be recommended as disinfectants.

Coal tar, Creasote, and Carbolic acid have all a power of combining with animal and vegetable substances and preventing their decomposition. Creasote is especially recommended to prevent the smell from cancerous sores.

INFEFTMENT, in the law of Scotland, from the same origin as the English term feoffment, expresses the ceremony by which a person succeeding to another by descent, settlement, or conveyance, is invested in any heritable or real property. This ceremony was, until quite recently, as pure a feudal usage as it ever had been in the days when the almost universal inability to write suggested symbolical modes of changing possession. A number of persons had to proceed to the ground, consisting generally of the solicitor who prepared the titles, and his clerks, who had the following parts to act. One was the bailiff of the superior, and a commission authorising him to act in that capacity was read over. Another party acted as the procurator or representative of the purchaser. The bailiff lifted some fragments of earth and stone from the soil and handed them to the procurator, as symbols by which, according to the authority given to him, he made over possession of the lands to the new owner. The receiver of the symbols then placed a coin of the realm in the hands of another party, who must have been a notary public—this being the form in which a protest is taken in the hands of a notary in Scotland. Two other parties acted as witnesses. The ceremony, with the authority on which it proceeded, was narrated in a deed called an instrument of sasine, in which the notary publicly attested the transaction. The preservation of this cumbrous ceremony down to so late a period was owing to its connection with the admirable system of registration which has kept the commerce in real property in Scotland on so clear and secure a position; for the whole ceremony went for nothing unless the instrument were recorded in the Register of Sasines within sixty days after the ceremony. This registration was, and in modern usage is, the criterion of preference; for the person whose sasine is first registered has the absolute title, all questions as to the fairness of the transaction being pecuniary questions to be settled apart from the title to the lands. The cumbrous ceremony mentioned above has been rendered unnecessary by modern legislation. Conveyances and other deeds are now, in most cases, registered themselves; the public registration of the deed, or of instruments setting out the nature thereof, or otherwise analogous to the instrument of sasine, coming in place of the infeftment and registration formerly in use.

INFINITE, INFINITY, INFINITESIMAL, INFINITESIMAL CALCULUS. The word infinite is literally "without bounds," and when applied in an absolute sense to magnitude means that its quantity is utterly unlimited, so that there is no conceivable and determinable magnitude but what is less than the infinite magnitude.

The notion of infinity is therefore at first purely negative, but it does not long remain so: for we are forced upon what we take the liberty of calling a definite notion of infinity, by our consideration of time, space, and number. We cannot, if we would, annihilate our conception of space, or confine it within certain limits; nor can we suppose duration to have an end. Even if we imagine our own annihilation we cannot rid ourselves of the idea of something else existing, with the permanent conception of unbounded space and time. If we try to conceive all sentient existence at an end, we know from reasoning that it may be we ought to suppose also the annihilation of space and time: but the constitution of our minds will not permit it, and so long as we exist to think, even about our own non-existence, the reality of space and time will prevent our conceiving their destruction. Whether the preceding be good or bad metaphysics is perfectly indifferent in an article on the use of the word infinite in the exact sciences: the ideas expressed, true or false, are those which will, in the first instance, present themselves to the mind; and those who object to one method of expression will embody the same thoughts in another.

The other extreme in the scale of quantity is the perfect absence of all magnitude, expressed in the word "nothing" or the technical term "zero." It is necessary to treat the two together in mathematical reasoning, since all difficulties which belong to the one term belong equally to the other. We have also to consider the words "infinitely small" as well as "infinitely great."

There are three distinct methods of proceeding in regard to the employment of these terms in mathematical reasoning. Firstly, we have those who would use the words "infinite" or "nothing" in their absolute sense, relying upon the reality of the conception which they have of the things signified by them. Secondly, there are others who would entirely banish the use of the words, because in their absolute sense they do not represent assignable magnitudes. Thirdly, others admit the use of the words, guarding them by definitions which point out the processes in the expression of the results of which they may be employed.

To the first it is answered that the absolute use of ∞ and 0 (the mathematical symbols of infinite magnitude and absence of all magnitude) in the same manner as symbols of definite quantity, is extremely liable to lead to error; which was never entirely avoided by the advocates of this system, except by abandoning their theory, and applying in practice the maxims alluded to under the third of the preceding heads. The absurdity of an absolute and unrestricted use of these terminal symbols may be very easily shown, if it be maintained that they are to be used precisely as other symbols. For example, it will readily be conceded that if a times x be y, and if b times x be y, then a and b must be equal. Now twice an infinite magnitude is infinite, and three times an infinite magnitude is infinite, therefore 2 and 3 must be asserted to be equal. The advocates of the unrestricted use of ∞ and 0 avoid such results by a method of selection which amounts to keeping within the definition presently to be noticed.

To the second of the three sects above mentioned it may readily be conceded that they have a right to refuse any branch of mathematical reasoning, so far as themselves only are concerned. But we deny that the code of mathematical controversy contains any such axiom as that "mathematics is the science of assignable magnitudes only," by which to claim the submission of an opponent. The general rule is, that mathematical demonstration exists wherever there is logical deduction from universally obvious maxims with respect to magnitude. Nor does the word "universally" here mean that such maxims must have been obvious to every individual of the human race. If so there would be no such thing as mathematical demonstration: for there have been found instances in which persons have denied that the sum of all the parts makes up the whole. It would not be very easy to lay down a rule by which it should be determined what fraction of dissent is fatal to an axiom, but the following appears to us to be the practice. When any individual who has been successful in advancing the mathematical sciences, and whose talent and originality are widely known, disputes what is usually received as a first principle, it is customary for subsequent writers on the same subject to preserve his objections, and place them before the reader. If two or three such persons unite in an objection, the fact of there being a majority of the same class on the other side would not save the principle attacked from being considered as dubious. All differences which affect results are very soon settled; but those which only array one mode of attaining a certain conclusion against another, depending as they do for the most part upon the manner in which fundamental and indefinable terms are understood, are generally perpetuated from one age to another. Now it is a proposition which is very rarely disputed, that the science of mathematics is conversant with more than assignable magnitude, and that the notion of infinity, though requiring to be used with care, is one with regard to which sound and obvious maxims of reasoning may be laid down.

We proceed to state these principles, that is, to enunciate the method followed by the third of the sects mentioned. If we look at the manner in which we derive the notion of infinity, we shall not find any one who imagines that he absolutely grasps infinite space, time, or number, by one single and independent conception of his mind. To space, space may be added, to this again space may be added, and so on without limit, until the space thus accumulated is greater than any definite space [INDEFINITE] which was named at the outset of the process. From thence comes the notion of infinite: we cannot imagine the greatest possible space, because any space, however great, being distinctly conceived, we can as distinctly conceive a greater. Consequently the phrase "space is infinite," whatever more it may imply, certainly may be allowed to stand for an abbreviation of the preceding two sentences. And in like manner, if we see a conclusion—which we can nearly attain by the use of a large magnitude, more nearly by the use of a larger, and so on without limit, that is to say, as nearly as you please, if we may use a magnitude as large as we please, but which is never absolutely attained by any magnitude however great—then such conclusion may be said, for abbreviation, to be absolutely true when the magnitude is infinite. It may appear to some as if the conclusion, under the preceding circumstances, is really true when the magnitude is infinite: this may or may not be the case, but the mathematical use of the word infinite does not require the question to be raised. The convention under which that term is introduced demands that the preceding conditions shall be fulfilled, and excludes the word whenever they are not fulfilled: those who think that the fulfilment of the conditions makes that which we call a convention a necessary consequence, meet on common ground with those who would reject the absolute notion of infinity. The former are allowed their own words, and their own result, together with their own method of arriving at it; the latter are not required to use the word infinite, except as an abbreviation: to the mere collocation of the letters which compose that word they can hardly object, and the conditions of its introduction are precise and intelligible. We shall now give a few instances of the development of propositions in which the word infinite appears.

1. When z is infinite, A is equal to B. This may be said in abbreviation of the following:—When z is great, A is nearly equal to B; A may be made as nearly equal to B as you please if we may take z as great as we please; but no value of z, however great, will make A absolutely equal to B.

2. A finite quantity x, divided by an infinite quantity, is nothing. If x be divided by a comparatively great quantity, the quotient is small; this quotient may be made as small as you please, if we may take the divisor as great as we please; but no divisor, however great, will make the quotient absolutely equal to nothing.

3. Every circle is a regular polygon of an infinitely great number of infinitely small sides. An inscribed polygon of a large number of small sides nearly coincides with the circle; a polygon may be made to coincide with the circle as nearly as you please, if its number of sides may be as great as we please, and their lengths as small as we please; but no polygon, however great its number of sides, and however small the sides, can absolutely coincide with the circle.

4. When x is infinite A and B are both infinite; but A is infinitely greater than B. This may be said when if x increase, A and B both increase, so that A and B may both be made greater than any quantity you name, provided we may make x as great as we please: provided also that A increases faster than B, so that when you name any number, however great, we, being allowed to make x as great as we please, can make A contain B more than that number of times.

5. When $x=a$, z is infinite. This may be said when z is great if x be nearly equal to a, and may be made as great as you please, if x may be made as nearly equal to a as we please: provided that, however near x may be to a, z has still an assignable value.

The preceding instances are sufficient to show what is meant when the terms "infinity," "infinite," or "infinitely great," appear: we now proceed to the correlatives "nothing," "infinitely small," "evanescent," &c. The independent use of the term "infinitely small," as laid down by some writers, is yet more difficult than that of infinitely great. If A be an assignable magnitude, x is said to be infinitely small when it is so small that it is absolutely incomparable to A, so that $A+x$ and A may be taken as equal. Now, unless x be absolutely equal to nothing, this cannot be; so that the infinitely small quantity, as thus defined, can have no magnitude whatever. Here we seem to rest, not in an absurd, but in a useless conclusion: for what possible benefit can arise from inventing a new word to stand for the *nothing* by which two equal magnitudes differ. A little further consideration of the term "nothing" will here be necessary.

There is one process of arithmetic which yields an absolute zero, namely, subtraction. From a take a, and nothing remains. Consequently, in considering the idea of the absence of all magnitude, we usually refer it to the result of that process by which it is directly and unambiguously obtained. But from no other process of arithmetic does this idea arise, except by the same train of ideas which leads us to the use of the word infinite. We cannot, for example, obtain the quotient "nothing" by dividing one finite magnitude by another; we can make the result small, smaller, as small as we please, but not absolutely nothing. When therefore we consider an equation made by addition and subtraction of terms, the absolute result 0 may be used without reservation: thus, $2x+3=a$, and $2x+3-a=0$, may be written for each other without any particular examination of the symbol 0. But in any other case we can only consider 0 as the limit towards which we approach by an interminable succession of diminutions, no one of which is ever final, corresponding to the interminable succession of augmentations by which we attain the notion of infinite. In strict analogy therefore with our former proceeding (mutatis mutandis, we repeat our words) if we see a conclusion—which we can nearly attain by the use of a small magnitude, more nearly by the use of a smaller, and so on without limit, that is to say, as nearly as you please by the use of a magnitude as small as we please, but which is never absolutely attained by any magnitude however small; then such conclusion may be said, for abbreviation, to be absolutely true when the magnitude is nothing. The sentences immediately following the first occurrence of the preceding words may now be repeated, only changing "infinite" and "infinity" into "nothing."

But in the meanwhile the term infinitely small does not appear, and its use seems to be superseded by that of the word "nothing." And it is true that "nothing," introduced under the preceding conditions, might supply the place of an infinitely small quantity. But since there is an absolute use of the term "nothing," derived from subtraction, to which the mind clings, and of which we do not find the like in connection with the term infinity, we shall, after some further explanation, use the term infinitely small instead of "nothing."

Our explanation of the term infinite will readily show the meaning of the following assertion; two infinitely great quantities may have a finite ratio. As follows:—when A and B are great their ratio may be nearly, say that of 10 to 7; when they are still greater they may be still more nearly in that ratio, and so on; and their increase may be so regulated that the greater they become the more nearly is their ratio that of 10 to 7; or as nearly as you please, if they may be as great as we please. Similarly, strictly remembering the preceding conditions for the introduction of the word "nothing," we may allow of the introduction of the following phrase:—two nothings may have a finite ratio. This means that A and B, both diminishing together, may diminish in such a way that when both are small their ratio may be nearly, say that of 5 to 3; when they are still smaller they may be still more nearly in that ratio, and so on: and their diminution may be so regulated that the smaller they become the more nearly is the ratio that of 5 to 3; or as nearly as you please, if they may be as small as we please.

But the idea of two nothings which have a finite ratio, however strictly defined in accordance with the preceding conditions, shocks even many of those who can grasp the method of using the word "infinity." The absolute nothing of subtraction has possession of the field, and it is not worth while to contest it for the use of a word. The term "infinitely small" therefore supplies the place of "nothing" whenever the latter is introduced under the conditions correlative to the conditions under which the use of infinitely great is allowed. But it must be remembered that if the infinitely small quantity thus introduced be added to or subtracted from a finite quantity it makes no change in the latter; just as if it were the nothing of arithmetic. A few instances of the development of propositions will now be given.

1. When A is infinitely small B is infinitely great. As A diminishes B increases, and B can be made as great as you please, if A may be taken as small as we please.

2. An infinitely small arc of a curve is equal to its chord. The smaller the arc the more nearly are the two in the ratio of 1 to 1; and the ratio may be made as nearly as you please that of 1 to 1, if the arc may be taken as small as we please.

3. Of two infinitely small quantities, one may be infinitely smaller than the other. When two magnitudes, A and B, diminish together, the smaller they are made the greater may be the ratio of A to B, in consequence of B diminishing much faster than A; and it is possible that A may be made to B in as great a ratio as you please, if both may be made as small as we please. The sine and versed sine of an angle are instances. Both diminish without limit with the angle; but the smaller the angle the greater the number of times which the sine contains the versed sine; and this to any extent whatever.

Infinitely small quantities thus used have been called infinitesimals, and a succession of infinitely small quantities, each of which is infinitely smaller than the preceding, is said to be a series of infinitesimals of different orders. Such a series is x, x^2, x^3, &c., in which, by making x sufficiently small, any one may be made to contain the next as often as we please. The infinitesimal calculus is a name sometimes given to the differential calculus, when presented by means of the theory of infinitely small quantities, in the manner originally propounded by Leibnitz.

The preceding considerations refer to the substance of nearly all the disputes which have arisen about the first principles of the differential calculus [DIFFERENTIAL CALCULUS]; and the different systems noticed in that article (with the exception of that of Lagrange [FUNCTIONS, THEORY OF]), spring out of different views of the manner of presenting the same idea.

In the article ANGLE we have taken notice of the circumstance that an extension of the word "equal" to infinite spaces which coincide, would allow of a proof of the well-known assumption of Euclid. [PARALLELS.] Let us suppose two equal angles having their sides infinitely extended. We have then two infinite spaces, of which it may readily be proved that either may be made to coincide with the other throughout its whole extent. And if any two angles be taken, and infinite spaces be drawn, it may be easily shown that the infinite space of the greater angle is greater than the infinite space of the less. The comparison of such infinite spaces is therefore possible consistently with perfect clearness in the meaning of the terms employed, and a simplicity of reasoning which would convince any one who is capable of the most ordinary thought. Had Euclid been accustomed to the modes of thinking which involve the idea of infinite magnitude, under any form whatsoever, it may be reasonably suspected that he would have admitted the following axiom, "Magnitudes which can be made to coincide in all their parts are equal," as applicable to infinite as well as finite spaces. Not having done so, the adherence to his standard has to this day excluded the only proof of the theory of parallels which does not assume the axiom of Euclid or an equivalent. For demonstration see PARALLELS.

There is a word which confusion of ideas is bringing into use in the sense of infinitely small; namely, *homœopathic*. The confusion is as follows. The system of medicine called *homœopathy* (which means *treatment by similarity*), proceeds upon the doctrine that diseases can be cured by use of the medicines which would produce *similar* diseases in a healthy person. But the homœopathic practitioners *also* hold that excessively small doses, millionths, billionths, decillionths, of grains, are sufficient for cure. The general public, which more readily apprehends the unusually small amount of the doses than the principle on which they are given, has accordingly appropriated the word *homœopathic* as a synonyme of *infinitesimal*.

INFLAMMATION (from *inflammo*, to burn). When any part of the body is preternaturally hot, red, swollen, and painful, such a part is said to be inflamed, or in a state of inflammation; and when these symptoms prevail to a certain extent, or affect very sensible parts, that general constitutional disturbance called fever is excited.

Inflammation may be either acute or chronic, circumscribed or diffused, common or specific. The term common, or healthy inflammation, is applied to all those inflammations which occur in a person otherwise healthy, which run a regular course, are usually of an acute character, and terminate in one of the conditions hereafter to be described. Specific, or unhealthy inflammation, unless produced by the direct action of a morbid poison, as that of syphilis, variola, &c., never takes place in a healthy individual, but is always modified by some pre-existing peculiarity or abnormal condition of the system, frequently hereditary, and is generally chronic. Although pain, heat, redness, and swelling, characterise inflammation in its most ordinary forms, it is by no means uniformly attended with all these symptoms; this is a circumstance which depends on the anatomical structure of the part affected, and on the duration and kind of the inflammation.

Terminations.—Inflammation is said to terminate in three ways:—by resolution, suppuration, and mortification. By the first, which is the most frequent mode of termination, is meant a gradual subsidence of the swelling, a diminution of the heat, pain, and redness, and an abatement of the fever; the parts return to their natural size and colour, and no pus or matter is formed. Suppuration is said to have taken place when the inflammation goes on to the formation of pus; the swelling then becomes more prominent, of a shining red colour, and soft in the centre; if now no artificial opening be made, the matter obtains exit through one or more orifices produced by the absorption of the walls of the cavity in which it is contained, and the abscess, in popular language, is said to have burst. Mortification is the least frequent but most severe mode in which inflammation can terminate, and usually is productive of great constitutional disturbance; when it is the result of a high degree of inflammation, the attendant pain is exceedingly severe, the bright red colour of the part becomes livid, and vesicles form on its surface; complete death of the part then takes place, and the pain abates, but the pulse is small and feeble, and great prostration of strength, with troublesome hiccup, are the constant attendants.

Causes.—The remote or exciting causes of inflammation are produced either by mechanical violence or by the action of chemical or other agents; but it sometimes occurs spontaneously, or without any perceptible cause for its production. With regard to the proximate cause, this is a question which is not so easily solved; it has occupied the attention of pathologists from the earliest times, and the number of theories on this subject attest the number of those who have interested themselves in the inquiry. The older pathologists imagined that all inflammations were produced by a fluxion, or flow of certain humours to a part, and the peculiar nature of the swelling was supposed to depend upon the kind of humour; thus blood produced phlegmon, bile produced erysipelas, &c. After the discovery of the circulation of the blood by our immortal Harvey, Boerhaave appears to have been the first who applied the discovery to the solution of this complicated question; he supposed that the minute blood-vessels became obstructed by the viscidity of the blood, or where this viscidity did not previously exist he imagined that the larger globules of the blood passed into the small vessels and blocked them up. But change in the consistence of the blood being found inadequate to explain all the phenomena of inflammation, it was supposed that the vessels themselves contributed chiefly to its production, and the doctrine of spasm of the extreme arteries began to prevail. Mr. Hunter considered inflammation to be a restorative principle by which injured or diseased parts are repaired, and the act of inflammation he regarded as an increased action of the vessels, which at first consists simply in an increase or distension beyond their natural size.

The application of the microscope to the investigation of the condition of an inflamed part has very materially changed the views of pathologists with regard to the nature of inflammation. If the tissues of an animal in a state of inflammation be examined, the following phenomena may be observed. 1. The capillary vessels of the part are observed to be narrowed, and the blood in consequence flows through them more rapidly. 2. The vessels from being narrower than natural become larger, and now the blood flows through them more slowly but evenly. 3. Changes go on in the capillary vessels, and the flow of blood is observed to be irregular, not even, as in the second stage. 4. If the observation be continued, the blood is seen to be arrested altogether in the capillaries, and these vessels appear to be distended to the utmost. 5. The last and most important phenomenon in the series is, that the liquor sanguinis of the blood is seen to exude through the walls of the blood-vessels, and is sometimes accompanied with the red blood corpuscles, which pass through either the softened or ruptured walls of the capillary vessels. The most important of these changes, and that which perhaps constitutes the essential element of the inflammatory process is the exudation of the lymph or liquor sanguinis.

In view of these phenomena, modern pathologists have adopted many theories with regard to the nature of the changes undergone by the tissues in this state. Whilst some have thought the blood globules themselves were at fault, others have attributed the state to the condition of the nerves of the part, and others again have traced the changes to the condition of the capillary vessels. All however agree, that inflammation involves an altered supply of blood to the inflamed part, and a changed condition of the nutritive processes of the blood.

The results of this process, although summed up in the three terminations before mentioned, may be still further developed. Thus with Mr. Paget, we may divide these effects into *productive* and *destructive*. The productive effects are effusions or exudations which are susceptible of permanent development, and also of degeneration. The destructive effects of the inflammatory process are softening, degeneration, absorption, ulceration and death of tissue, or mortification. We will here merely indicate the nature of these results.

Effusion or *exudation*. According to the tissue in which inflammation occurs, will be the liquid nature of the exudation. In serous membranes the exudation is attended with so much water or serum, that large accumulations of water take place, producing what is called dropsy or effusion. A good example of effusion from inflammation is the action of a common blister. In all cases of effusion of serum, a quantity of fibrin is poured out which is left after the water has been absorbed. This is seen in inflammation of the peritoneum, pleura, and pericardium. The distinction between effusion from obstruction, and effusion from inflammation is, that the latter contains organisable matter, whilst the former does not.

Blood is sometimes effused during the process of inflammation by the rupture of the capillaries. This effusion must not be confounded with hæmorrhage from accidental rupture, which produces quite a different appearance in the part. The latter is bright red, whilst the former is yellow-red or brown.

The plastic matter exuded from the blood-vessels during inflammation is called "inflammatory lymph," or "coagulable lymph," or "exudation." Its most characteristic general properties are, that it is capable of spontaneously organising itself, and that thus organised it may proceed by development to the construction of tissues like the natural structures of the body. It is, however, occasionally modified, and, instead of producing natural structures, it produces structures different from those existing in the body. The exudation, producing new or heterologous formations, has been called by Williams *kakoplastic;* whilst Bennett divides exudation into *simple, tuberculous.* and *cancerous.*

The *simple* variety of exudation produces different results, according to the following circumstances :—

1. The nature of the tissue in which the exudation takes place.
2. The time at which an exudation is examined after its occurrence.
3. The state of the blood in which it takes place, as in small-pox, scarlet fever, &c.
4. The amount of vascularity of the affected part.
5. The amount of local exudation.
6. The suddenness with which the exudation has taken place.
7. The persistence of the inflammatory process.
8. The amount of fluid or water poured out with the inflammatory lymph.

These circumstances modify the appearances which will be presented by an inflamed part, and will also modify to a less considerable extent the local and general symptoms of inflammation.

On examining the lymph or exudation under the microscope, it is found to consist of a liquid containing in it corpuscles which are called "exudation cells." They are rough on the surface, and about the [illegible]th to the [illegible]th of an inch in diameter, and at first present neither a distinct cell-wall nor nucleus, but afterwards a distinct nucleus is seen in them. From the lymph thus constituted proceed all the forms of secondary deposits which are found resulting from inflammation. These primordial cells pass into all the conditions of texture which are found in the tissue in which inflammation takes place, as muscle, nerve, bone, &c.

These cells are exposed to various forms of degeneration. When what is called suppuration comes on they form the "pus cells," and other cells which have been described by microscopic pathologists. Suppuration is either circumscribed, diffused, or superficial. The circumscribed is well seen in the common abscess, boil, or phlegmon. The diffused in phlegmonous erysipelas and purulent infiltration, whilst superficial suppuration is observed in purulent ophthalmia and inflammation of mucous surfaces.

The result of the tuberculous and cancerous forms of exudation is the production of deposits known by the names of cancer and tubercle. [Cancer : Tubercle.]

The destructive effects of inflammation are seen in softening, absorption, ulceration, and mortification more particularly. In softening there is little or no plastic power in the lymph thrown out, and the tissues attached lose their natural cohesiveness. This *softening* occurs in inflammation of the mucous membranes, of the brain and spinal cord, and of the bones. *Absorption* frequently occurs with softening, and this is seen in the common process of the pointing of an abscess, in which the tissues soften and are absorbed.

Ulceration occurs on open surfaces, and is the result of an exudation of inflammatory lymph, in which the corpuscles are formed into pus-cells, and an absorption of the inflamed tissues takes place. Such an absorption may take place entirely independent of blood vessels, as in cartilage, and is nevertheless called ulceration. Granulation is a reparative process that occurs in ulcerated surfaces, and consists in the organisation of the lymph thrown out from the ulcerated surface, and eventually leads to the reparation of the parts destroyed by the softening and absorptive processes. *Mortification* takes place when the vital processes of inflammation cease in a part. Parts more or less extensive, or the whole of an organ may display this tendency. It may be attended with effusion, or it may be dry. All the tissues are liable to the occurrence of this termination of the inflammatory process.

General Symptoms.—The symptoms attendant on inflammation will vary of course with the extent, position, and nature of the local affection. It should, however, be recollected that an extensive inflammation may come on slowly, and not present any general symptoms at all, and that the general symptoms of inflammatory fever may be present without any inflammation. There are however certain general symptoms of inflammation which are so frequently present that they constitute what is called inflammatory symptomatic or sympathetic fever. This fever is attended with premonitory symptoms of coldness and shivering, which are succeeded by a reaction. The pulse, which is at first small and slow, becomes quick and hard. There is thirst, and greatly increased heat of surface. The secretions are diminished, the skin is dry, the bowels are confined, the urine is scanty. There is pain frequently in the loins and head. There are restlessness and anxiety, and occasionally delirium. The respiration is quickened. The tongue is coated, white, and moist. These are the symptoms of inflammatory fever of an active kind, but it is not unfrequent to have this fever from the beginning presenting an adynamic type. This has been named *typhoid inflammatory fever*. It is accompanied with great feebleness. The pulse sinks, the skin becomes moist and cold, the features are pinched, the tongue is dry and becomes black. Low muttering, delirium, and stupor are present. These symptoms may be present from the first, or occur when some unhealthy change takes place in the character of the local inflammation.

Hectic fever is another form of inflammatory fever. It accompanies those conditions of the inflamed part which are called suppurative. This fever is attended with remissions. In the day the fever is slight, but it recurs at night, and is attended with heated skin, and flushed red face, "hectic spots." The fever is at its height at midnight, and is succeeded by colliquative sweats, and frequently accompanied by diarrhœa.

Treatment.—Of course the treatment of inflammation must vary according to its seat, extent, and nature of the general symptoms. When the inflammation is of the simple kind its tendency is towards health, and the less interference there is the better. The great question that has been raised on the treatment of inflammation is the propriety of blood-letting in acute forms attacking important organs. The pathological views given above have greatly modified the notion that bleeding was the best remedy in all forms of inflammation. It does not appear that the abstraction of blood exercises any important influence on the inflammatory process at all, and Dr. Hughes Bennett maintains that its influence on the system is injurious, hence he forbids bleeding for the sake of the inflammation. In certain inflammations, however, as of the lungs, the circulation of the blood is greatly retarded, and in these cases bleeding, by lessening the volume of blood, facilitates the circulation, and is to be recommended. The local abstraction of blood from an inflamed part has also been found to relieve the pain and consequences of the inflammation in a particular organ, and this process is to be recommended where the part can be got at.

Mercury, which was formerly recommended in all inflammations, is now only very cautiously given by some practitioners, under the conviction that it subsequently interferes with healthy nutrition. When given it is seldom pushed so far as to produce salivation. Other remedies for inflammation are tartarised antimony, digitalis, aconite, nitrate of potass, chlorate of potass, saline and other purgatives. The properties of these medicines are treated of under their proper headings, and the treatment of inflamed conditions of the more important organs will be found under the heads of these diseases, or of the diseases of particular organs, as Pleuritis; Peritonitis; Heart, Diseases of; Kidneys, Diseases of; Skin, Diseases of, &c.

(Hunter, *On Inflammation;* J. Hughes Bennett, *Principles and Practice of Medicine;* Watson, *Lectures on the Practice of Physic;* Aitken, *The Science and Practice of Medicine;* Wedl, *Pathological Histology;* Simon, *Lectures on Pathology;* Paget, *Lectures on Surgical Pathology.*)

INFLEXION. [Diffraction.]

INFLEXION. A point of contrary flexure [Flexure, Contrary] is sometimes called a point of inflexion.

INFLUENZA (*La Grippe*, Fr.). Influenza is the name given by the Italians to an epidemic catarrh, which has spread more extensively than any other epidemic; and this universality of its attacks, together with the greater severity of its symptoms, principally distinguishes it from common catarrh. It attacks all ages and conditions of life, but is seldom fatal except to the aged, or to those previously suffering from or having a tendency to pulmonary disease. Notwithstanding the great frequency of this epidemic, it is remarkable how little variety there has been in its symptoms, and the records of cases which occurred in 1510 nearly resemble those which have been observed during its latest visitations. The following are the symptoms which most generally characterise it:—The person is seized with slight chills; weight and pain, sometimes severe, are felt over the eyebrows; there is an increase of the lachrymal and nasal secretions, with loss of appetite, prostration of strength, a weak frequent pulse, dyspnœa, hoarseness, and cough. When death has taken place, the post mortem appearances have revealed acute inflammation of the mucous membrane lining the air-passages, or pleurisy and pneumonia. The duration of the disease varies from one or two days to a fortnight; but great debility often remains behind for many weeks, and in some epidemics relapses have been frequent.

Several epidemics of influenza have been remarkable for affecting the mucous membrane of the alimentary canal, as well as that of the organs of respiration. The cases occurring towards the subsidence of the epidemic are generally less severe than those at its commencement.

The history of this disease is curious. When once it has made its appearance it pursues a regular course from one country to another, from continent to continent, across seas and over mountains; but this course, although regular as regards each epidemic, yet varies somewhat with most. In 1510 its course was in a north-westerly direction; in 1557 due west, attacking whole populations almost on the same day; in 1580 from east and south to west and north, and was complicated with plague, but France was the only European country infected that year with the latter. The epidemic of 1729 was very fatal in London; Lowe says more persons died of it than at any one time since the plague of 1665. In the month of September, 1729, 1000 weekly were carried off by it in the metropolis. The epidemic of 1803 travelled from south to north. England was also severely visited in 1831, 1833, and 1836–7, and it figures more or less in all the yearly returns of mortality in every year since. It is worthy of note, that in all these epidemics the lower animals have suffered. The destruction of horses and cattle in 1836–7 was very great. Dogs, cats, and birds also suffer, and it is even said fish.

These epidemic visitations have taken place most frequently in the spring and autumn, but have seldom remained at one place longer than six weeks. In 1836 it broke out in Cape Town in Africa at the same time as in London; in the one place it was mid-summer, in the other mid-winter.

On the exciting causes of this, as of all other epidemics, we must confess our ignorance. Some have attributed it to the sudden changes of weather; others to a particular morbid principle, different from but resident in and conveyed by the air; and others again to contagion. The first of these hypotheses is evidently untenable, for atmospheric changes as great and sudden have taken place as some of those observed to precede the breaking out of the epidemic, and yet none has appeared, and an epidemic has occurred without being preceded by any apparent atmospheric peculiarity; the sensible state of the air, too, preceding and accompanying the same epidemic has been different in different places. The doctrine of contagion, although it has had more advocates than either of the former hypotheses, does not appear to rest upon any better foundation. It remains, then, to examine the validity of the second hypothesis—namely, the existence of a morbid principle resident in and conveyed by the air. Now the very doubts on any subject which give rise to theories for explaining the phenomena connected with such subjects presuppose the want of any direct proofs or evidence of a tangible shape; and if—putting aside the idea of the epidemic we are speaking of being caused by any deleterious or unwholesome quality of our food—we allow the atmosphere to be the medium of conveyance of the morbid principle, we must admit that all endeavours hitherto made with the view of demonstrating such principle have only afforded negative results; neither does it appear that there is any one spot on the earth whence it emanates.

However great the discordance of opinion on the cause of this malady, all physicians of eminence have agreed remarkably in their testimony as to the general rules and principles of practice. Notwithstanding the inflammatory nature of this disease, bleeding is ill borne, and can rarely be employed with safety, much less with benefit; and persons who have been subjected to this operation recover more slowly than others, and remain in a debilitated condition much longer. In severe cases, emetics at the commencement have been found useful, either in cutting short the disease or in moderating its violence. Mild aperients administered with caution, the exhibition of antimonial and saline medicines, and a cool temperature, constitute the means which experience has found to be most efficacious during the acute stages of the disease; whilst quinine and stimulants are beneficial in the latter stages.

INFORMATION, an accusation or complaint exhibited against a person for some criminal offence. It differs from an indictment principally in this, that an indictment is an accusation found by the oath of a grand jury, whereas an information is simply the allegation of the officer who exhibits it. Informations are of two sorts: those which are partly at the suit of the crown and partly at that of a subject; and secondly, such as are in the name of the sovereign only. The former are exhibited for numerous offences inferior to felony, as wilful and corrupt oppression by a justice of the peace, libels, conspiracies, &c., and are filed by the master of the crown-office. The latter are filed by the attorney-general at his own discretion, and are called *ex officio* informations. The former kind, which are called criminal informations, can only be filed by leave of the court of Queen's Bench, and the application for leave must be supported by affidavits which the party complained of has an opportunity of answering. When an information of either kind is filed, it must be tried in the usual way by a petit jury in the county in which the offence was committed.

When it is necessary for the Court of Chancery to interfere with the regulation or management of any charity, the attorney-general, on the relation of some informant (who is called the relator), files an information in the Court of Chancery for the purpose of bringing the case before the court.

Proceedings in the Exchequer for the recovery of duties or penalties are also called informations.

INFORMER. An informer is a person who lays an information or prosecutes any person for some offence against the law or a penal statute. Such a person is generally called a common informer, because he is supposed to make a business of laying informations for the purpose of obtaining his share of the penalty. Persons are induced to take the trouble of discovering offences, for which a pecuniary penalty is inflicted on the offender, by the promise of the reward; and if the penalty is imposed for the public interest, he who makes the offender known does the public a service. But still the business of a common informer is looked on with dislike, and he who follows it is generally despised; and perhaps the character of common informers is generally such that they deserve all the odium they receive. They stand in a like situation to the common hangman. This dislike of informers, simply as such, is one of the anomalies of society, who hate their benefactor. The real foundation of the dislike, however, among those who can form a just judgment of things, is, not the act of information, but the devices, tricks, and meannesses to which a man must often resort, in order to know the facts on which his information must be founded. It is the same principle which often leads us to condemn a man for making certain statements in public, not because of the statements, but because of the means by which he may have obtained his knowledge. When a penalty is too heavy, or when the law that imposes it is generally disliked by the people for any reason, good or bad, the popular dislike finds a definite object in the informer who gives effect to the law. The legislature that made the penal law is overlooked, because the legislature is a number of persons; the informer is one, and his agency is seen and felt.

In absolute governments there are spies and political informers, who are the tools of a government which has no rule but its own pleasure. Some people have been dull enough to confound all informers in one class, not seeing that there is a difference between an informer who helps to give effect to the law, and an informer who helps a tyrannical government to entrap and punish persons suspected of disaffection to the government or of designs against it.

INFUSIONS are solutions of some of the principles of vegetables, generally in water, but occasionally in other vehicles. When water is employed it may either be hot or cold. It is customary to use warm water, but in many instances cold is preferable. Where cold water is used, it is necessary to continue the digestion longer than when it is warm. The vegetable substances may either be fresh or dried: when the former, they are to be cut to pieces; when the latter, bruised or very coarsely powdered, never reduced into a fine powder. The water, being poured on the substance employed, is to be allowed to stand in a covered vessel for a space of time varying with the nature of the article submitted to maceration. It must be strained, and is then fit for use. Infusions generally spoil soon, more particularly if warm water be employed, or if the substance contain starch or other fermentable ingredients. Sometimes alcohol is added, after straining, to assist in keeping the infusion, or to increase its powers. Hard water should, if possible, be avoided in the preparation of infusions.

Concentrated infusions, to be diluted to the ordinary strength at the time of employing them, are now prepared on a large scale by wholesale chemists for the use of general practitioners, as they have not only the advantage of keeping better, but avoid trouble and loss of time. Other improvements have been introduced, such as making the infusions by percolation, or, as it is termed by the French, *par déplacement*. Also, Appert's mode of preserving vegetables has been applied [ANTISEPTICS]; and concentrated or preserved vegetable juices have been recommended and adopted by Mr. Squire ('Pharmaceutical Trans.,' No. iii., p. 94, Sept., 1841) and Dr. Bentley. These have many advantages. For infuso-decoctions, see DECOCTIONS.

INGROSSING. [ENGROSSING.]

INHIBITION, in the law of Scotland, is a proceeding by which a creditor may prevent his debtor from alienating property either to favoured creditors or to other persons. Nominally it affects all property; but it is only in the case of real property that, from its being put on the register, it is efficacious. The debt on which inhibition may proceed must be founded on some obligatory written document, or established by the decree of a court. The process may be recalled if improperly awarded. It conveys no specific security to the person who holds it, but it gives him a right to impugn every act which the debtor does to his prejudice after the inhibition. If the inhibition be followed by proceedings to attach the estate at the instance of other creditors, the inhibitor has a preference over them if the debts have been incurred subsequently to the inhibition, but not otherwise. The mixed rights thus occasioned are often productive of very intricate questions.

INJUNCTION *in Equity*. An injunction is a writ, issuing by the order and under the seal of a court of equity, to restrain parties from proceeding in other courts, from negociating notes or bills of exchange to prevent the sailing of a ship, the alienation of a specific chattel, to prevent waste by felling timber or pulling down buildings, the infringement of patents or copyright, to repress nuisances, and to put an end to vexatious litigation. It is impossible here to enumerate the variety of cases in which a plaintiff in equity is entitled to the relief afforded by the writ of injunction.

An injunction may be obtained *ex parte*, and behind the back of the defendant (as the phrase is), immediately after filing a bill, upon motion supported by affidavit; or it may be moved for after the defendant has answered the plaintiff's bill, and on the merits of the case as appearing from the defendant's answer; and if an injunction has been obtained *ex parte*, the defendant may immediately move to dissolve it on affidavits, even before he puts in his answer.

An *ex parte* injunction, that is to say, without notice, cannot be moved for after the defendant has appeared.

INJUNCTION *at Law*. By the Patent Law Amendment Act, 1852, power was given to any court in which an action for infringement of patent should be pending to direct an injunction if it should see fit.

By the Common Law Procedure Act, 1854, courts of common law may grant an injunction, when claimed upon the writ of summons, in cases of breach of contract, or other injury, where the party injured is entitled to maintain and has brought an action. Such injunction is by way of supplement to the common judgment, and is against the repetition or continuance of such breach of contract, or other injury, or the committal of any breach of contract or injury of a like kind, arising out of the same contract, or relating to the same property or right.

This common law injunction has seldom been applied for, or obtained; and a bill has recently been introduced into the House of Lords by Lord Chancellor Campbell, for, *inter alia*, enabling courts of law to grant upon motion exclusive protection against probable violation of legal, as distinguished from equitable, rights. The Roman interdiction was in many respects similar to the injunction. [INTERDICT.]

INJURY, INJURIES. Blackstone, after treating of Rights, proceeds in his third book to "consider the wrongs that are forbidden and redressed by the laws of England." He then divides wrongs into two sorts or species—private wrongs and public wrongs. To private wrongs he also gives the name of civil injuries, as being "the infringement or violation of the private or civil rights belonging to individuals considered as individuals." Public wrongs are "a breach and violation of public rights and duties," and "are distinguished by the harsher appellation of crimes and misdemeanours."

The true nature of *injuria* is, however, contained by implication in another expression in Blackstone: "The contemplation of what is *jus* is necessarily prior to what may be termed *injuria*." For as *jus* is law, so *injuria* is something that is not jus, or is forbidden by jus. An injury, then, in the English law, is some illegal act; but the word is commonly used to express an illegal act done to a man or his property, for which he may by legal process get compensation. The English legal maxim that a man cannot recover damages or compensation when there is a *damnum absque injuria*, contains in it the true meaning of injuria or injury. The act must be an illegal act in order to entitle a man to compensation. If a man's acts damage the property of another, without being such acts as are forbidden, the person who is damaged can get no compensation. For instance, a man may set up a grocer's shop next door to another shop, and get all his neighbour's custom, which is a grievous *damnum*, but no *injuria*. It is true that the nature of the damage may in some cases help to determine whether it is a legal injury or not; but the true question always must be whether the act complained of is either at common law or by statute an injuria, an unlawful act.

The Roman word *injuria*, as already observed, signifies generally anything which is done contrary to law (quod non jure factum est, hoc est contra jus). In its narrow sense, *injuria* was limited to unlawful acts that affected a man's person, not his property, at least not directly. It comprehended personal violence, such as beating a man, and using abusive words to him, and libelling him. Injuria might be done to a man either in his own person or in the person of those who were in his power, as his children and slaves, or in his hand (manu), as his wife. The mode of proceeding was by the *actio injuriarum*. (Gaius, iii. 220–225.)

The nature of Roman *injuria*, in its limited sense, is, therefore, it appears, different from that of injury in English law, as properly understood; for injuries in English law, or civil injuries, or private wrongs, as Blackstone calls them, comprehend all the wrongs that are treated of in his third book—that is, all wrongs except crimes and misdemeanours. The Roman *injuria* belongs both to the head of law criminal and non-criminal. In some cases damages were got; in others, the offender was punished in his person: in some cases he might be punished by a pecuniary penalty and in his person also.

INK, for the various purposes to which it is applied, is composed of very dissimilar ingredients. It may be treated of under the heads of *Writing Ink*, *Indian Ink*, *Printers' Ink*, *Marking Ink*, and *Sympathetic Ink*.

Writing Ink.—The writing ink of the ancients was essentially different from that which is now employed. Its basis was finely-divided charcoal, mixed with some mucilaginous or adhesive fluid; it was much less destructible than modern writing ink, and more resembled printers' ink, both in the nature of its colouring ingredient and its indestructibility.

Writing ink is now a chemical compound, and not a mere mechanical mixture. Its basis is proto-gallate and proto-tannate of iron, which by oxidisement becomes per-gallate and per-tannate; and it is owing to the oxygen of the air effecting this change gradually that recent writing is of a comparatively light colour, and that it subsequently becomes black. Many processes have been given for preparing writing ink. The common ingredients are galls and sulphate of iron; in fact, while printers' ink may be considered as a black paint, writing ink may be regarded as a black dye. The following, which is recommended by Mr. Brande, gives, he says, an excellent ink, and it possesses the merit of greater simplicity than most others:—Aleppo galls, bruised, 6 ozs.; sulphate of iron, 4 ozs.; gum arabic, 4 ozs.; water, 6 pints. Boil the galls in the water, then add the other ingredients, and keep the whole in a well stopped bottle, occasionally shaking it. In two months strain and pour off the ink into glass bottles, which must be well corked. To prevent mould, add one grain of corrosive sublimate, or three drops of creasote, to each pint of ink. Mr. Brande observes, that, "In making good writing ink the great object is to regulate the proportion of sulphate of iron to the galls. If it be in excess, although the ink may at first appear black, it becomes subsequently brown and yellow. Hence some time should elapse before ink is used after the ingredients are put together, in order to be tested from time to time, and the combinations perfectly regulated." Gum is added to retain the colouring matter in suspension, to prevent too great fluidity in the writing, and to protect the vegetable matter from decomposition. Logwood and other vegetable astringents have been tried, but do not yield a permanent ink.

When writing has through age become yellow and indistinct, it is because the vegetable matter has decayed, and mere rust, or peroxide of iron, is left. By carefully applying infusion of galls, the writing may be rendered blacker and more legible. This method was successfully adopted in deciphering the MS. of Gaius, a work on Roman law which attracted great attention among learned men in Germany about forty years ago, and which for a long time resisted all attempts to decipher it. Modern writing ink, unlike the ancient, is readily destroyed by chlorine, acids, and alkalies. Indeed, if paper has been made from inferior rags, bleached by excess of chlorine, the ink, however good, will be ultimately discoloured. Sulphate of copper is occasionally added to ink, and some authorities direct it to be prepared with the addition of vinegar; but these substances are rather injurious than otherwise.

Blue writing ink is now much used; made sometimes from indigo, and sometimes from Prussian blue as a basis.

Indian Ink.—The cakes of this ink are made of lamp-black and size or animal glue, with the addition of perfumes or other substances not essential to its quality as an ink. It is used in China with a brush, both for writing and for painting upon paper of Chinese manufacture. It is used in Europe for designs in black and white, in which it possesses the advantage of affording various depths of shade, according to the degree of dilution with water. The common lamp-black of the shops is not sufficiently fine for the purpose; it requires to be made with peculiar care.

Printers' Ink is of two kinds: for letter-press printing and for copper-plate printing. Printers' ink is prepared by boiling linseed or nut oil in an iron pot; and if it does not take fire of itself, it is kindled, and suffered to burn for about half an hour; the flame is then extinguished by closely covering the vessel; and the oil is by this operation found to have acquired the necessary drying quality, after being again boiled. It is then mixed with a proper quantity of lamp-black, when black ink is required; if red ink be required, the colouring matter employed is vermilion, for finer works. Copper-plate printer's ink is made with oil which is less boiled, and the charcoal used is stated to be Frankfort black, made from vine twigs.

Marking Ink is employed for marking linen: it is a solution of nitrate of silver, written with a pen upon the fabric to be marked, after the latter has been moistened with an alkaline solution, as potash or soda. By this process oxide of silver is precipitated upon and combines with the cloth so as to be scarcely removeable by any re-agent which does not also destroy its texture.

Sympathetic Inks are such as are invisible until heat is applied, and then, by the chemical change induced, the writing becomes visible. The most remarkable of these is that prepared from cobalt, called Hellot's sympathetic ink, which is a chloride of the metal. When the written paper is held to the fire so as to evaporate the water, the letters become green.

The subject of ink has lately undergone much discussion, arising out of a paper read by Mr. Underwood before the Society of Arts. In 1857 the firm of which he is a member was applied to by the Government for an ink that would yield many copies of any written document, by means of some kind of copying machine. It was determined that the ink and the paper should have certain chemical relations, such as that of throwing down a precipitate. The best mode was found to be, to steep the paper in a neutral chromate of potash, and to use a solution of extract of logwood as ink. By preparing three different strengths of solution, it was found possible to obtain from two to twenty copies of any document. A copying-ink has also been prepared, applicable both to printing and writing—a desideratum in many commercial establishments. The printing is first effected; and the ink so printed is rendered partially soluble by moisture when the copying by the press is to be done. Of course the colour and depth of the ink can never be otherwise than faint, by any use of the copying-press. The modern ink-makers candidly admit that the ancients excelled them, in the blackness and durability of their ink. In Durham Cathedral there is a copy of the Bible, written by the Venerable Bede, in which the ink is still beautifully black. Indeed there are numerous MSS. in existence, written from the 5th to the 13th centuries, of which the same may be said. Dr. Lewis, about a century ago, expressed an opinion that the ancient ink consisted of fine charcoal suspended in some mucilaginous fluid; and in this opinion Mr. Astle afterwards supported him. Sir Charles Blagden, some years later, applied chemical tests to many old writings, which afforded proof that the ink was not a mere mechanical mixture, but a true chemical compound. That there were different qualities of ink, then as now, is certain. A parchment document is in existence, written in 1099, containing many certificates written at different religious houses in England; and these, though written nearly at one time, exhibit all shades from faded brown to deep black. Mr. Underwood thinks that some of the old ink was merely a carbon *pigment*, but that other kinds were veritable *dyes* of iron and acids, with a good deal of carbon added.

In reference to printing ink, it may be remarked that the ink of the first *block* books is found usually to be bad; whereas that of the first *moveable type* books is much better—so much so, indeed, as to excel the general kinds of modern ink in depth, brilliancy, and richness of black. Printing ink is, indeed, a compound of very peculiar character; for, in order to be really good, it should possess these four qualities—to distribute freely and work with sharp, defined outlines on the type; to have a greater affinity for the surface of paper than for that of type, in order to transfer readily; to dry much more quickly on paper than on type or an inking-roller; and to be proof against the effects of time and chemical re-agents. We may here state that the bank-note ink, made by Mr. Winstone, is prepared from coal-tar naphtha; this naphtha being burned in close chambers, the smoke or soot is collected, and exposed in a retort to a heat sufficient to drive off all volatile matter; the soot is then ground up with a peculiar varnish, producing a printing ink of intense blackness, which prints off with great fineness of outline, and dries so as to be fit to handle almost immediately.

The miscellaneous kinds of ink, under the names of *japan, invisible, horticultural, lithographic, autographic*, &c., need not be described; they are mostly mere varieties of those already noticed; while one of the number is described under LITHOGRAPHY. *Ink powder*, sometimes useful in travelling, is generally made by mixing the ingredients dry, and adding boiling water in certain proportions when required for use. Leonardi's *alizarine* or *solid ink*, introduced in 1858, at Dresden, is made of Aleppo galls, Dutch madder, sulphate and acetate of iron, and sulphate of indigo, combined into the form of small round cakes; a portion of one of these cakes is dissolved in water when required for use.

INLAYING, is the art of inserting pieces of one substance in cavities cut in the surface of another, as a means of ornament. The substances may be various kinds of metal, or various kinds of wood, or pearl, ivory, tortoiseshell, &c.; and the product may either be regarded as a work of art, or as an ornamental article of furniture. It is in the latter sense that inlaying is chiefly regarded. Two kinds which had much celebrity in their day, but are perhaps less practised at present, are *buhl* and *reisner* work. These were named from two *ébenists*, or cabinet-makers: Buhl, or Boule, an Italian who settled in Paris in the reign of Louis XIV.; and Reisner, a German who settled in the same city soon afterwards. Buhl mostly used a brass inlay on a tortoiseshell ground; Reisner a dark wood inlay on a tulip-wood ground; but it is obvious that the varieties admit of almost interminable change. Where the substances are not too hard to be easily cut, the devices are produced by counterpart sawing; that is, two thin plates are laid one on another, and a very fine saw is worked through both of them, in lines marked out by a pencil device. If we suppose that two veneers or thin layers of wood, one black and one white, were thus treated, there might be two pieces of inlaying produced—the one a black inlay on a white ground, and the other a white inlay on a black ground; for one veneer would exactly fit the holes cut in the other. The saws for this work are mounted in bow or arched handles; they are very narrow and thin, and are worked in short quick movements. In Buhl work, the patterns generally consist of continuous lines, of which the honeysuckle is a familiar example; this does not require the actual separation into small pieces, and thereby marks one point of difference between *inlaying* and *mosaic*. The veneers are temporarily glued together, or rather to a sheet of paper placed between them; the design is drawn on one surface, the material is held loosely in a vice by the left hand, a small hole is made with an awl in a part of the design not very conspicuous, the saw-blade unloosened from its handle is thrust through this hole, the saw-handle is then fixed, and the workman proceeds with his sawing—dexterously turning the saw and the material about so as to make the tortuous cut correspond with the lines of the design. Sometimes three or four veneers are cut in this way, affording means for greatly varying the colours of the inlay.

The ornamental stone-work called *pietra dura* bears more resemblance to inlaying than to mosaic; for the holes are not cut *through* the ground, but only to a certain depth, in slabs of black marble; and small bits of other coloured marble are inserted to this limited depth. The inlaying of knife and fork handles with studs of gold and silver, is similarly effected by drilling holes to a certain depth, and inserting fragments of gold or silver wire. The inlaying of papier-maché with pieces of mother-of-pearl, or other iridescent substances, is not strictly *in*-laying in the sense here employed: for the decorative substance, cut into the forms of leaves, flowers, or other devices, is laid *on* the papier-maché, and a general level produced by many thicknesses of varnish—in the way described under PAPIER MACHÉ.

The delicate fine-art workmanship of mosaic, produced by the juxtaposition of numerous small pieces of enamel, is described under MOSAIC; while the application of wood in ornamental devices to flooring, is treated under MARQUETRY AND PARQUETRY.

In the Jury Reports of the Great Exhibition it is said, in reference to the gold and silver work in the Indian collection:—"Herein the least possible amount of metal is so treated by delicate hand-labour, by exquisite pierced work, enamelling, and *inlays*, combined with such a thorough consideration of the treatment of surface by buhl-work, &c., as to give the greatest amount of skilled workmanship with the smallest quantity of material. . . . . . The Eastern nations largely practise the art of inlaying both in metal and in other materials; their weapons of war are decorated with inlaid work."

INN. The responsibility of innkeepers for the safe custody of the goods and chattels of their guests is one out of the numerous classes of cases that arise upon the law of bailments, and is placed by Sir W. Jones, in his Treatise, under the second subdivision *Locatio Operis*, of the general head *Locatum*. The law makes the innkeeper responsible for the safety of the goods of persons coming to his house, in the language of the ancient writ, *causâ hospitandi;* but he may be released from his liability either by inattention on the part of the guest to such reasonable rules as the innkeeper may think proper to lay down for the protection of the property of his guests,—by any act of negligence on the part of the guest himself,—or by his making use of the house not, as it is before said, *causâ hospitandi.* Thus, if an innkeeper requires his guest to put his goods under lock and key, and the guest leaves them in a passage, whereby they are lost; or the goods are stolen by the guest's own servant; or the guest uses his room in the inn as a show-room, into which a number of people are allowed to have access, and not as a lodging-room, the responsibility of the innkeeper ceases. The general interest seems to require that the law should be made still more strict as against innkeepers, as the good faith and responsibility of the innkeeper form the only security of the traveller. The Roman law on this subject is contained in the Digest iv., tit. 9.

(Smith's *Leading Cases*, 'Calye's Case;' *Treatise on the Law of Bailments*, by Sir W. Jones.)

INNS OF COURT AND OF CHANCERY. The establishment of these houses of law is usually considered to be one of the effects of Magna Charta, which, by fixing the Court of Common Pleas at Westminster, brought together a number of persons who (as Spelman says) addicted themselves wholly to the study of the laws of the land, and no longer considering it as a mere subordinate science, soon raised those laws to that pitch of perfection which they suddenly attained under the auspices of King Edward I. They purchased at various times certain houses between the city of London and the palace of Westminster, for the combined advantage of ready access to the latter and of obtaining provisions from the former. "For their liberties and privileges" (observes Mr. Agard, in an essay written in the end of the 17th century), "I never read of any granted to them or their houses: for having the law in their hands, I doubt not but they could plead for themselves, and say, as a judge said (and that rightly), that it is not convenient that a judge should seek his lodging when he cometh to serve his prince and his country."

In Fortescue's time there were four inns of court and ten inns of chancery, the former being frequented by the sons of the nobility and wealthy gentry, and the latter by merchants and others who had not the means of paying the greater expenses (amounting to about "twenty marks" per annum) of the inns of court. On working days, most of these students, he says, apply themselves to the study of law; and on the holy days to the study of Holy Scripture. But it appears that they did not entirely neglect lighter pursuits, for, says the same learned author, they learn to sing and to exercise themselves in all kind of harmony, and they also practise dancing and other noblemen's pastimes. He says they did everything in peace and amity, and although the only punishment that could be inflicted (as the case is now) was expulsion, they dreaded that more than other criminal offenders fear imprisonment and prisons.

The inns of court, formerly called "hostels," or in French, "hôtel," are Lincoln's Inn, the Inner Temple, the Middle Temple, and Gray's Inn.

Lincoln's Inn appears to have taken its present name from Henry

Lacy, earl of Lincoln, whose house near Holborn had been for some time inhabited by students of law. It has a chapel built by Inigo Jones, the interior of which is very striking, and a noble hall and library, erected in 1846, from the design of Mr. Hardwicke, and recently ornamented by an elaborate and excellent fresco by Mr. Watts. The library contains a very large and well selected collection of books, and a great many very valuable MSS., amongst others those of Sir Matthew Hale. A studentship, worth about 100*l.* a year, to be held for eight years, was founded by Christopher Tancred, Esq., for four students, to be educated in the study of the law at Lincoln's Inn. They are elected by the trustees for the time being of the Tancred Charities. The garden must have been much curtailed since the reigns of Henry VII. and Henry VIII., when, according to Mr. Lane, special enactments were made to prevent the students from hunting the rabbits in it.

The Inner Temple.—This inn, as well as the *Middle Temple*, owes its name to the Knights Templars, who established themselves here about 1185. After their dissolution the Temple came into the hands of "divers professors of the common law that came from Thavyes Inn in Holburne." In the reign of Henry VIII. the members of the Temple had divided into two societies known by the names of the Inner and Middle Temple, each having a hall and a library.

The church is common to both societies. It was founded by the Templars, upon the model of that of the Holy Sepulchre at Jerusalem, and consists of a round tower at the western entrance, and three aisles running east and west, and two cross aisles. In the tower are tombs of eleven of the Knights Templars, but with the exception of one, Geoffry de Magnoville, afterwards earl of Essex, it is not known whom the effigies represent.

Gray's Inn is on the north side of Holborn. It takes its name from the Lords Gray of Wilton.

Each inn of court is governed by its own benchers, or "ancients," as they were formerly called, who fill up the vacancies in their own body, usually selecting queen's counsel, and thus practically vesting the appointment in the Lord Chancellor. At Lincoln's Inn the governing body is called the council, at the Temple the parliament. Their power is undefined, and sometimes assumed to be unlimited. In the two Temples and Gray's Inn, the benchers appropriate to a large proportion of their number, chambers, which they may either occupy or let; so that in this way large sums are often received by the fortunate seniors of the body. See farther, BARRISTER.

Besides these four inns of court, there are eight inns of chancery, which are now only used as chambers, and are principally inhabited by solicitors and attorneys. These are *Furnival's Inn*, *Thavie's Inn*, *Clifford's Inn*, *Clement's Inn*, *New Inn*, *Lyon's Inn*, *Staple Inn*, and *Bernard's Inn*. Several of the inns of chancery have a hall, in some of which dinners are provided and terms kept, but they are now merely private societies.

INOCULATION is the insertion of a morbid fluid formed in the body of one person into that of another. It has however been more particularly applied to the practice of producing small-pox by removing a small quantity of the fluid formed in the pustular eruption on the skin of one person and inserting it beneath that of another. The latter (if he have not already suffered from the disease) will, after the lapse of from seven to ten days, be affected with it; but its severity, when thus engendered, is in a large majority of cases greatly mitigated, so that the proportion of those who die after inoculation is not greater than one in five hundred; while of those who receive the small-pox casually one perishes in every six.

The practice of inoculating for the small-pox was introduced into this country by Lady Mary Wortley Montagu, about the year 1721, her son having thus received the disease during her residence in Constantinople. It had long been practised in Turkey and other Eastern nations, and its utility was well known before its introduction into England, both in the south of Wales and in the Highlands. Mungo Park also found that it was habitually practised by the negroes on the Guinea Coast. It was very slowly adopted in this country, and it was not until it had been practised on six criminals (whose liberty was promised to them if they recovered, as they fortunately did) that it was generally received. It was then almost universally had recourse to, till the introduction of vaccination; but since that time it has most deservedly fallen into disuse. Indeed whatever were the merits of inoculation in lessening the severity of the small-pox in the person inoculated, it was probably on the whole productive of more harm than benefit, by introducing the disease (as it certainly often did) into a district previously free from its contagion; and thus, while it saved the life of one person, it became the cause of the death of many who caught small-pox from him. It is now very rarely practised, and the exposing in public ways or places of persons having the small-pox is punishable. [VACCINATION.]

Of the other eruptive fevers, measles and scarlatina are communicable by inoculation, though with some difficulty and without the advantage of rendering the disease at all milder; but chicken-pox cannot be thus transmitted, and it is at present doubtful whether the exanthematous typhus fever can. Other cases in which diseases are produced by inoculation are treated of in separate articles, as HYDROPHOBIA, &c.

INOCULATION is an operation performed on numerous species of Exogenous plants, and, like grafting [GRAFTING], has for its end the vital union of one species or variety with another. This object may be effected by either of the two operations in the case of many species; but particular circumstances sometimes render inoculation the more proper method, as in the cases of the apricot and peach, which expand their leaves early in the spring, long before growth has commenced in the plum stock, on which they are generally worked. The grafts of such early vegetating trees are generally found to be exhausted before the stocks can contribute a sufficient quantity of fresh organised matter for completing the union. It is therefore found most advantageous to bud or inoculate them in the summer, when both scion and stock are in a state of equal vegetation.

Buds, like grafts, may remain alive for some time after having been inserted on their stock, and may even effect a sort of adhesion to it; but it is only when the alburnum of the two parts, in a nascent state, come in contact, that a permanently vital union is accomplished. Unless this be previously understood, the best instructions with regard to the performance of the operation will be liable to misapplication.

All buds have their origin in the medullary sheath, and are situated in the axils of leaves existing or that have existed; but when a bud has developed itself beyond the external bark, it begins to produce and send down layers of liber, and its connection with the medullary sheath is at that time destroyed. If the bud so detached be placed in favourable circumstances on the alburnum of another allied species, it will derive moisture from the cambium, and continue to vegetate till the granulations of cellular matter resulting from the effort of the stock to cover with fresh matter the part wounded by the introduction of the bud, meet with the alburnum elaborated by the inserted bud; the similar substances then coalesce, and the union may be termed complete. It may be here observed that the opening made for the reception of the bud should not be made too large, for the smaller the portion of bark raised the sooner will it become covered with fresh matter, and meet with that which is forming at the base of the bud.

The season for performing the operation is, generally speaking, from the beginning of July to the middle of August, the particular time varying according to the season. The best criterion is the state of the buds and the degree of cohesion between the bark and alburnum of the stock. If the buds on the young shoots have become so far perfectly formed outside as to bear separation from the branch, and if the bark of the stock can be freely raised, and exhibit an abundance of cambium in a fluid state, the operation may be proceeded with. If, on the contrary, the bark adheres rigidly to the alburnum, or *is set*, as it is technically expressed, there is little chance of success.

In the selection of buds it is necessary to distinguish those that are formed for blossom-buds and those that would produce shoots in the following season. For example, in the case of peach-trees trained against walls, no buds with only a single leaf at their base should be taken, for such, if the tree is in a bearing state, will only produce a blossom, even if it should remain on the tree; and when transferred it will either perish in winter or die after an imperfect development. On vigorous young trees in the open ground that are not in a blossoming state single *wood-buds* may be readily found, and they are preferable to all others. When a bud on a wall has two leaves at its base it will produce from thence one *wood-shoot* and a blossom-bud; in fact, although only one bud is apparent, yet there exist two; since every leaf has in its axil either a bud or the rudiments of one. Thus a shoot having buds with three leaves at their bases developes itself in the following spring, in the form of two blossom-buds and a wood-bud in the centre.

The operation of budding, or inoculation, is performed in various ways; but the best and most general is that called shield-budding or T budding, from the resemblance of the two cuts made in the bark of the stock to the two principal bars of the Roman letter T. In a smooth part of the stock a horizontal cut is made through the rind down to the alburnum; but care is taken that the incision only just reaches the alburnum. From the middle of this another cut is made downwards. The bud is then shaved off the shoot by entering the knife about half an inch below it, then cutting nearly half way through the branch immediately below where the bud is seated, and finally by slanting the knife outwards about half an inch above the bud. A portion of bark and young wood will thus be taken along with the bud; but the wood must be carefully separated by being dexterously jerked off *downwards* in the direction of the woody fibre, leaving only the small portion belonging to the base of the bud. If the wood were detached by pulling upwards, this minute formation of alburnum belonging to the bud would likewise be removed, and with it the *root*, as it is called, of the bud, or vital speck. This will sometimes happen, whichever way the wood is removed, and may be known by the appearance of a small hole below the external convexity of the bud. When this happens the operation must be repeated. The bud being thus prepared and its bark pared so as to be easily introduced below that of the stock, and as much reduced as its immediate connection with the bud will permit, the bark of the stock is raised with the thin flat ivory handle of the budding knife by entering it at the angles formed by the transverse and perpendicular incisions above described, taking care not to disturb the bed of cambium; on the latter the bud, with its shield-like portion of bark, is placed, its upper part being then cut off, so as to coincide with the transverse section on the bark of the stock; the lips of the perpendicular incision are closed, or at least brought down upon the shield of the bud; and the whole is bound down with a strip of pliable matting, the point of the bud only being missed by the bandage. The latter must be untied and slightly re-tied when the swelling of the stock indicates the necessity of the operation.

INOSIC ACID ($C_{10}H_7N_2O_{11},HO$?). This acid is a constituent of the juice of meat. It is best prepared from the flesh of the common fowl. Fresh lean of fowl is to be finely chopped and digested in its own weight of water; the filtered liquid heated nearly but not quite to the boiling point, to coagulate albumen; baryta water added to separate phosphoric acid, and the filtrate then evaporated till of the consistence of thick syrup: it is now diluted with alcohol till it becomes milky, and set aside. After a time crystals appear, which are inosate of potash, and of baryta, if excess of the latter base has been used. The crystals are redissolved in warm water, and chloride of barium added. On the cooling of the solution, inosate of baryta crystallises out, and requires only another crystallisation to be obtained perfectly pure. This salt has the composition ($BaO, C_{10}H_7N_2O_{11} + 6Aq$).

Inosic acid may be isolated from the baryta salt by the cautious addition of sulphuric acid. Its dilute solution in water has a very acid reaction, and an agreeable taste, resembling juice of meat. It may be concentrated, by a heat not exceeding 140° Fahr., to the consistence of syrup, but cannot be made to crystallise. It is insoluble in alcohol or ether. The name inosic acid was given to this body by Liebig, its source being thereby indicated (*ἴς, ἰνός*, muscle).

INOSITE ($C_{12}H_{12}O_{12} + 4HO$) is a peculiar species of sugar, discovered by Scherer in the juices obtained from the flesh of animals. It crystallises in large crystals, which have a sweet taste, but which are not susceptible of vinous fermentation. It yields, however, both lactic and butyric acids when exposed to the action of casein. It differs from glucose in its not giving the usual reaction with the salts of copper and potash, and in possessing two atoms more water in its composition.

The following is the characteristic reaction for inosite: the solution suspected to contain this body is evaporated to dryness on platinum foil with nitric acid, then the residue is moistened with ammonia and a little chloride of calcium added, finally on evaporating again to dryness the residue becomes of a beautiful rose colour. Neither starch nor any of the sugars produce this reaction, which is so delicate as to admit of the detection of less than the $\frac{1}{100}$th part of a grain of inosite.

INQUEST. [CORONER.]

INQUISITION, THE, of which the more correct title is the Holy Office (*Sanctum Officium*), is the name of an ecclesiastical tribunal established in the 13th century by popes Honorius III., Gregory IX., and Innocent IV., to try heretics, blasphemers, apostates, relapsed Jews or Mohammedans, witches and wizards, polygamists, and other persons charged with infractions of the canons of the Church. The judges of this court were called inquisitors, whence the tribunal itself has been commonly styled the "Holy Inquisition." The name of inquisitors, or inquirers after heretics, appears as early as the reign of Theodosius I., who, by his constitution against the Manichæans and other heretics, A.D. 382, after adjudging the punishment of death for several aggravated cases of heresy, directs that "Inquisitores and conquirendos et eruendos hereticos" be appointed by the prefect of the Prætorium. ('Codex Theodosianus,' Gothofredi, xvi., tit. 5, lex 9.) This is the first law under the Christian emperors by which the punishment of death is awarded for heresy. Constantine had only sentenced the Arians to banishment, though he threatened to punish with death those who should retain and make use of the books of Arius. The subsequent law of Honorius, A.D. 398, expels from the towns the "Clerici" or priests of the Montanists and Eunomians, and if they persist in bringing people together, it banishes them for life. It further orders their books to be burnt, and condemns all persons who are found to conceal them to be beheaded. ('Cod. Theod.' xvi., tit. 5. l. 34.) Two more constitutions or laws of Honorius (51 and 56 of the same book and title in the Theodosian Code) threaten with proscription and death those who publicly profess certain heresies. These are the oldest laws on record which make heresy a capital crime; but it ought to be observed, that there is no law in the whole Theodosian Code which subjects heretics in general to the pain of death, that punishment being reserved for the leaders, those who collected assemblages of people, made proselytes, and preached or spread certain heterodox doctrines specified and condemned by the laws. The trial and punishment in all such cases were left to the civil magistrate.

Previous to the time of Theodosius I. there had been persecutions of Arians by the Orthodox, and *vice versâ*, carried on through the violence of individuals; but there was no specific law making heresy a capital offence. Towards the heathens the case was different. Constantius (A.D. 353) had forbidden heathen sacrifices under pain of death. Theodosius I. confirmed that law, and Theodosius II., after remitting the capital penalty (A.D. 423), put it in force again in 426. (Gothofredus, 'De Statu Paganorum.') Most of the earlier fathers, Tertullian, Cyprian, Lactantius, Hilarius, Ambrose, and Gregory Nazianzenus, and even Athanasius, openly disclaim violence as a means of enforcing unity and obedience to the Church. Chrysostom and Augustine however think that heretics ought to be prevented from holding assemblies, and ought to be confined or banished, but not put to death. But it ought to be remembered that the heretics of those times, the Arians and Donatists in particular, constituted political factions which rebelled against the authority of the state, murdered their antagonists, demolished their houses, and committed all sorts of violence, as may be seen by the letters of Augustine.

The first person on record who was juridically condemned and put to death for heresy is Priscillianus, the leader of a sect in Spain, in the latter part of the 4th century. Two Spanish bishops, one of whom was called Idacius, accused Priscillianus, with two other priests or bishops, before a council held at Bordeaux, A.D. 385. Priscillianus appealed to the emperor Maximus, who had assumed the imperial purple in Gaul, and who was then residing at Treves, whither Priscillianus and his friends were taken, being followed by their prosecutor Idacius. Martin, bishop of Tours, interceded in their behalf; but after his departure from Treves, Maximus entrusted Evodius, the prefect of the Prætorium, with the trial of the accused, and upon his report Maximus condemned them to be beheaded. This novelty was generally censured, and Ambrose and Martin of Tours strongly reprobated the part which Idacius had acted, and which they characterised as unbecoming the episcopal character. The consequence was, that Idacius was excommunicated, and died in exile.

Justinian, in the first book of his Code, in which he treats of the Catholic faith, and defines its creed according to the first four general councils, of Nicæa, Constantinople, Ephesus, and Calchedon, forbids public disputations upon dogmas, and enacts several penalties against heretics, Jews, and apostates. In the 131st Novel, the same emperor says: "We receive the doctrines of the four Holy Synods as the Divine Scriptures, and their Canons we observe as laws." Thus the orthodox creed, as expounded in the four councils, became the law of the empire, an empire which was then administered despotically, and dissent from that creed was an offence against the law. From this principle the whole penal code against heretics was derived. But for several centuries after, cases of heresy were tried and penalties awarded by the ordinary courts, as the bishops had not then any temporal jurisdiction. In course of time however councils interfered, and after condemning particular tenets as heretical, specified in some instances the punishments to be inflicted upon heretics, Jews, and apostates. [JEWS.] It became the practice for the bishops to examine the accused, and decide whether there were sufficient grounds for the charge of heresy against them; if the charge was proved, they were to admonish them, and convince them of their errors, after which, if the accused remained obdurate, the bishop handed them over to the secular court. "Heretici perseverantes in errore relinquantur Curiæ secularis judicio." (Council of Tarracona, A.D. 1242.) And the law of Las Partidas, which is still the fundamental code of Spain, promulgated in 1258, says: "Heretics may be accused by any one of the people before the respective bishop or his vicar, who must examine and interrogate them upon the various articles of the faith, and if they find that they err in them or in any other thing which the church of Rome commands to be believed and observed, he must endeavour to convert them and make them forsake their errors by means of good arguments and mild words. And when the penitents have acknowledged their belief, they are to be reconciled to the church and be forgiven. But if it so happens that they will not forsake their errors, the bishop must convict them as heretics, and then hand them over to the secular or lay judges." The lay judges however were not mere executors of the episcopal verdict: they examined the proceedings, and having convinced themselves of their regularity, they awarded the penalty. By a clause of the same law of Las Partidas, "the property of those who are condemned as heretics, or who die in the heretical belief, belongs to their children or other descendants." The principle of confiscation is here not recognised. This was in the kingdom of Castile; but in Aragon, France, and Italy, a different process was introduced by means of the Inquisition.

In the Council of the Lateran, convoked at Rome in 1215, by Innocent III., new and severe enactments were made against heretics, but the cognisance of matters of heresy was left to the ordinaries or bishops. But some years before this time, Innocent himself, of his own authority, had sent a commission consisting of two legates, who were Cistercian monks, accompanied by subordinate priests and officers, to the south of France, in order to extirpate the heresy of the Albigenses. These legates acted independently of the local bishops; they held their own court, before which they summoned, by the authority of the pope, individuals accused of heresy, and condemned, and inflicted penalties, and even capital punishments. Dominic de Guzman, the founder of the order of Dominicans, was one of the most zealous agents of this commission, the members of which were called Inquisitors. This however was only a temporary and local commission.

In 1208, Peter de Castelnau, one of the legates, who had become obnoxious for his severity, was murdered near Toulouse, and Innocent was so exasperated, that he preached a crusade against the Albigenses, which, after a long struggle, ended in their extermination. [ALBIGENSES.] Honorius III., the successor of Innocent, issued new provisions against heretics, which were enforced by the emperor Frederic II. in three constitutions, or laws, dated Pavia, 1224, by which he condemned impenitent heretics to death, and those who repented to perpetual imprisonment. In the year 1228 a severe penal law against heretics was enacted in the city of Milan by Cardinal Godfrey of St. Mark, papal legate, with the consent of the archbishop and the people; it was to the effect that "no heretic should be allowed to remain in the state of Milan; that any person might lay hands on a heretic and bring him before the magistrates; that those who were convicted as heretics by the Ecclesiastical Court should be executed by the prætor within ten days, their houses pulled down, and their property confiscated to the community." (Calchi, 'Historiæ Patriæ,' b. xiii.; Corio, 'Storia di Milano,' part ii., p. 72; Verri, 'Storia di Milano,' ch. ix.) No less than fifteen sects of heretics, with strange names, are enumerated by these historians as having been discovered within the state of Milan. The archbishop of Milan at the time was Enrico da Settala, who exerted himself greatly in rooting out the heretics, and having probably exceeded all bounds, he was at last banished by the council of the republic, for which the council and the podestá were excommunicated by the pope. In the inscription on the tomb of this archbishop, it was stated that "being appointed inquisitor, he destroyed the heretics." It was about the year 1233 that Pope Gregory IX. laid down the rules and defined the jurisdiction of the inquisitors courts, which he sent to various countries, under the name of Inquisitorial Missions. He appointed as chief inquisitor in Lombardy, Pietro da Verona, a Dominican monk, who was strenuously seconded by the then podestá of Milan, Oldrado da Tresseno, who consigned to the flames numerous heretics. The likeness of this podestá was, not many years since, and probably is still, seen sculptured in relief in the façade of the hall of the municipal council at Milan, with an inscription recording, among other things, that he had burnt the heretics as in duty bound: "Catharos, ut debuit, uxit." The chronicler Fiamma says, that he was the first who put heretics to death in Milan. By degrees inquisitors were sent by the popes to most Italian cities and states, where, with the consent of the local authorities, they established their tribunal, and had their officers, notaries, informers, and other agents. Dominican monks were generally employed as inquisitors, as the principal object of the institution of their order was to defend the orthodox faith by arguing and preaching against heresy, on which account they are styled "Fratres Prædicatores," or brother preachers. The inquisitor Pietro da Verona, in the course of nineteen years, burnt a great number of heretics throughout Lombardy, banished or frightened away a still greater number, and confiscated their property. A certain Confaloniere of Alliate, being warned that he was on Fra Pietro's list, conspired with several of his friends, who lay in wait for the inquisitor, and on the 6th of April, 1252, as he was returning from Como to Milan, in company with another Dominican, they killed him near Barlassina, and wounded his companion, who died a few days after. The inquisitor was shortly after canonized by Pope Innocent IV., under the title of St. Peter Martyr. In 1277, another Dominican, brother Pagano da Lecco, was killed in the same manner in Valtellina.

The chroniclers of the various cities of Lombardy record the acts of the inquisitors, and the number of heretics and witches whom they put to death at particular times. The chronicle of Muralto states that brother Antonio da Casale, inquisitor of Como, in 1416, sent three hundred heretics to the stake in one single year. Tartarotti states that in the year 1485 forty-one witches were burned at Como. Bartolomeo Spina, 'De Strigibus,' ch. 13, states that in the diocese of Como the number of those who were tried annually by the Inquisition exceeded one thousand; that the inquisitor employed eight, ten, and even more vicars, and that almost every year about one hundred persons were burned. ('Lettere del Conte Gianbattista Giovio all' Abate Bettinelli,' letter vi.)

The Inquisition was introduced into Rome as well as other parts of Italy by Gregory IX., and entrusted to the Dominicans, but it was a long time before it was established as a distinct and permanent court. Inquisitors were appointed by the pope on particular occasions, who visited the various provinces and towns, proclaiming to all persons the obligation they were under of informing against those whom they knew or suspected of being heretics, under pain of excommunication. At the same time they also made it known that all persons guilty of heresy who came of themselves before the inquisitor within a certain fixed period, and accused themselves and professed repentance, should receive absolution and be only subject to a canonical penance. These penances were public, humiliating, and very severe, as may be seen by a letter of St. Dominic concerning a heretic whom he had converted, by the acts of the council of Béziers, in 1233, and of the council of Tarracona in 1242. After the expiration of the period of grace, the inquisitor proceeded *ex-officio* against those who were denounced, the name of the informer being kept secret: he examined witnesses privately in presence of a notary and two priests, and having taken down the evidence in writing, he read it over to the witnesses, who were asked whether they confirmed what had been read. If there appeared to be sufficient grounds for proceeding against the accused, the inquisitor ordered his arrest by the municipal officers, and he was taken to the convent of the Dominicans, if there was one in the town, or to the prison of the ecclesiastical court. He was then interrogated by the inquisitor, and his answers might be used afterwards as evidence against him. If the accused denied the charge of heresy, he was supplied with a copy of the instruction and depositions, but without the names of the accuser and witnesses, and with the omission of such circumstances as might discover them. The accused having made his answer or defence, which was taken down in writing, if he denied the charges, the inquisitor, together with the bishop of the diocese or his delegate, if they thought proper, ordered him to be put to the torture in order to obtain his confession. The torture might be repeated three times, but it was afterwards ordered to be applied only once; this regulation, however, was often evaded by suspending the torments and then resuming them, and considering the whole as one torture. If in the end there were not sufficient grounds for the conviction of the prisoner, he was declared to be "suspected of heresy," was obliged to make a public abjuration of all heresies, and was subject to certain penalties, according to the nature of the case. If the accused was convicted of heresy, but professed his repentance, he was condemned to prison for life—a penalty which, however, might be mitigated by the inquisitor. But if he was a *relapsed*,—that is to say, had been tried before, and found guilty or only strongly suspected,—there was no mercy for him: he was "relaxatus;" that is to say, given over to the lay magistrate, who, according to the civil and canon laws, was bound to put him to death upon the sentence of the inquisitor which declared him a heretic. The only favour shown to the relapsed heretic who confessed and abjured his guilt was, to be strangled before he was burnt. If the convicted heretic was not relapsed, but impenitent, a respite of the sentence was granted in order to effect his conversion, and if he at last abjured his life was spared, and he was sentenced to perpetual imprisonment. If he persisted in his impenitence, he was publicly burned alive. Such were the principal characteristics of the old or delegated Inquisition as it existed from the 13th century to the latter part of the 15th, and the regulations of which are found in the 'Directorium Inquisitorum' of Friar Nicholas Eymeric, a native of Catalonia, and a Dominican monk of the 14th century, who held the office of chief inquisitor in Aragon for 42 years.

The Inquisition had nearly fallen into disuse in the kingdom of Aragon in the 15th century, in consequence of the total extinction of the heretical sects in the south of France, whose spreading on the other side of the Pyrenees had occasioned the introduction of the inquisitional courts into Catalonia and Aragon. In the kingdoms of Castile and Leon, and of Portugal, the Inquisition had not yet taken permanent root. But towards the end of the 15th century the Holy Office was introduced into Spain under a new and more appalling form, and became consolidated and permanent, and more absolute and independent than in any other country of Europe. This is what is designated by Llorente and other writers by the name of the 'Modern or Spanish Inquisition.'

Alfonso de Hodeja, prior of the Dominican convent of Seville, and Friar Philip de Barberis, inquisitor of the kingdom of Sicily, which was then subject to the crown of Aragon, suggested to Ferdinand and Isabella, in 1477, the establishment of the Inquisition in Spain for the purpose of punishing those Christians who secretly relapsed to the Jewish faith. The converts, or children of converts, from Judaism, were looked upon with dislike and mistrust by the old Christians; and many of them were at the same time among the wealthiest merchants and monied men of Spain, and as such had numerous debtors. Reports were spread of their secret meetings with those who had remained Jews, of their profaning the images of Jesus Christ, and even crucifying Christian children. Ferdinand easily listened to the suggestion; but Isabella, a princess of mild character, hesitated for some time, and without her consent nothing could be effected in the dominions of the crown of Castile. Means were at last found to alarm her conscience; she was told that the interests of religion required her acquiescence, and accordingly she solicited, by means of her ambassador at Rome, a papal bull, authorising the establishment of the Inquisition in the kingdom of Castile. The bull, despatched from Rome in November, 1478, authorised Ferdinand and Isabella to appoint two or three bishops or other dignitaries of the Church, aged at least forty years, of irreproachable character, graduates in theology and the canon law, who were to be commissioned to seek after and discover, throughout the dominions of the Spanish sovereigns, all apostates, heretics, and their abettors, with full power to proceed against them according to law and custom. Isabella, however, suspended the execution of the bull for two years, desiring at the same time that measures of persuasion should be adopted to warn the relapsed converts of their error and of their danger. A catechism was composed expressly for them, and several pamphlets against Judaism were issued. In 1480 the Cortes of Castile assembled at Toledo, and passed several restrictive measures against the Jews, with the view of checking their intercourse with the Christians. Nothing, however, was said in that assembly about the Inquisition. At last, in September, 1480, Ferdinand and Isabella, who were then staying at Medina del Campo, appointed two Dominicans as inquisitors, with an assessor and a fiscal attorney; and on the 9th of October a royal order was despatched to the governors of provinces to furnish the new inquisitors and their retinue with everything necessary for their journey to Seville; and at the same time their privileges were declared, which were the same as those granted by the Emperor Frederic II. to the inquisitors in Italy in the 13th century. The inquisitors established their court in the Dominican convent of St. Paul of Seville, whence, on the 2nd of January, 1481, they issued their first edict, by which they ordered the arrest of several "new Christians," as they were styled, who were strongly suspected of heresy, and the sequestration of their property, denouncing the pain of excommunication against those who favoured or abetted them. The number of prisoners soon became so great that, the Dominican convent not being large enough to contain them, the court was removed to the castle of Triana, in a suburb of Seville. The inquisitors issued another edict, by which they ordered every person, under pain of mortal sin and excommunication, to inform against those who had relapsed into the Jewish faith or rites, or who gave reason for suspecting them of being relapsed, specifying numerous indications by which they might be known. Sentences of death soon followed; and in the course of that year (1481) 298 new Christians were burnt alive in the city of Seville, 2000 in other parts of Andalusia, and 17,000 were subjected to various penalties. The property of those who were executed, which was considerable, was confiscated. (Mariana, 'Hist. de España,' b. 24, ch. 17.) The terror excited by these executions caused a vast number of new Christians to emigrate; several who were condemned as contumacious repaired to Rome, and appealed to Pope Sixtus IV. against the inquisitors. The pope wrote to Ferdinand and Isabella, in January, 1482, complaining of the arbitrary conduct of the two inquisitors appointed by them, revoking the authority which he had given to their majesties to appoint other inquisitors, and reserving that right to himself, which he exercised by a brief in the following February. Among these new appointments was that of the afterwards famous Torquemada. Queen Isabella now wrote to the pope, requesting him to give a permanent and fixed form to the new tribunal, and to make its judgment definite without appeal to Rome, complaining at the same time that she was accused of doing all that she had done in favour of the Catholic faith for the sake of the confiscations which follow the condemnations. The pope laid the proposal of Isabella before a committee of Spanish cardinals and bishops who were then at Rome, and among whom was Rodrigo de Borja, afterwards Pope Alexander VI. By their advice, Sixtus IV. despatched a brief to Isabella, appointing Manrique, archbishop of Seville, to be apostolic judge of appeal for all Spain, with power to decide on all appeals from the judgments of the Inquisition. By several other briefs, directed to the various archbishops of Spain, the pope gave them the power and regulated the manner of appointing the ordinary inquisitors in the various dioceses. Notwithstanding these measures, appeals from Spain continued to be received at Rome; and the pope again wrote, in August of the same year, to the Archbishop of Seville, ordering the proceedings against several individuals to be quashed, and recommending mildness and moderation. This recommendation however had no effect. Soon after, the pope appointed Thomas de Torquemada, prior of the Dominican convent of Segovia, to the new dignity of inquisitor-general of the kingdom of Castile; and by another brief, dated 17th October, 1483, he made him likewise inquisitor-general of the kingdom of Aragon, with full jurisdiction over all other inquisitors in Spain and its dependencies. His powers were confirmed by Innocent VIII., in February, 1486. Torquemada chose for his assessors and councillors two jurists, J. Gutierrez and Tristan de Medina: he created four subordinate courts, at Seville, Cordoba, Jaen, and Villa Real; the last was soon after transferred to Toledo. The Dominican monks, who had been appointed inquisitors by the pope in February, 1482, at first refused to submit to the authority of Torquemada, but they finally yielded. Ferdinand at the same time appointed a royal council of the supreme Inquisition, "Consejo de la Suprema Inquisicion,' of which the grand-inquisitor was president of right and for life, and a bishop and two doctors-at-law were councillors. The councillors had a deliberative vote in all matters of civil law, but the president alone judged in matters which concerned the canon or ecclesiastical law.

Torquemada and his two assessors framed the organic laws of the new tribunal, which were styled 'Instructions,' and were partly based on the older 'Directorium Inquisitorum' of Eymeric. Being sanctioned by a junta of the inquisitors of the four courts which he had established and of the royal councillors, the instructions, consisting of 28 articles, were promulgated at Seville, the 29th October, 1484. They are given at length by Llorente, in the sixth chapter of his History. New articles were added to them in 1488 and 1498; and, lastly, the inquisitor-general Valdez, in 1561, compiled a new series of ordinances in 81 articles, which regulated ever after the practice and proceedings of the Spanish Inquisition. They are also given by Llorente, in the 22nd chapter of his work. They are substantially the same as those already noticed as being in practice by the old Inquisition, but are more minute, and rather more unfavourable to the accused. By the old practice, for instance, the names of the witnesses for the prosecution were in many cases communicated to the accused, to whom they were of great use for his defence. Confiscation of the property of those who were condemned was not generally enforced under the old practice, and this was more particularly the case in the kingdom of Aragon, a circumstance which explains the resistance of the Aragonese, among whom the old or delegate Inquisition had been established for centuries, to the introduction of the new Inquisition as instituted by Torquemada.

Another important characteristic of the new Spanish Inquisition was its compact organisation and independence of all other authorities. The inquisitor-general was appointed for life; he was proposed by the king and approved by the pope. He appointed all other inquisitors under him, as well as visitors and other agents. He had full and discretionary power by the papal bulls in all matters of heresy. The grand-inquisitor, being thus placed as a distinct power between the king and the pope, was in reality independent of both. He could refuse to submit to those papal decretals and bulls which he did not approve, by alleging that they infringed upon the rights of the Spanish monarchy; and he could likewise evade the king's ordinances, by alleging the papal bulls which forbade the inquisitors to tamper with the secular power under pain of excommunication. Among other proofs of this assumed irresponsibility, one of the strongest is the famous trial of Carranza, archbishop of Toledo, in the reign of Philip II., who had attended Charles V. at St. Yusto in his last moments, and whom neither the briefs of the pope Pius IV., nor the remonstrances of the prelates assembled at the council of Trent could save from being confined in the prisons of the Spanish Inquisition for more than seven years, without a termination of his trial; and when at last pope Pius V. demanded of the Spanish inquisitor and of the king, under pain of excommunication, that the archbishop and the papers of his trial should be sent to Rome, all sorts of obstacles were thrown in the way of his departure and his final acquittal by the pope. After the death of Pius V. new proceedings were commenced in Spain to prove the archbishop guilty of heresy, and on the information being transmitted to Rome, Gregory XIII., who had succeeded Pius V., was, though with evident reluctance, induced to declare, on the 14th April, 1576, that the archbishop of Toledo was strongly suspected of believing sixteen propositions qualified as Lutheran, and which had been deduced from the context of his writings by the casuists of the Inquisition. He was then sentenced to five years' confinement in a Dominican convent and other canonical penances. A few days after this sentence, the archbishop, who was then seventy-two years of age, was taken dangerously ill, and before receiving the sacrament, on the 30th of April, he solemnly declared in presence of several witnesses "that he had never fallen into the errors with which he had been charged; that his expressions had been distorted into a meaning totally different from his; that he however humbly submitted to the judgment pronounced by the sovereign pontiff, and heartily forgave all those who had taken part against him in the trial, and would pray for them before the throne of Grace." On the 2nd of the following May the archbishop died in the convent of La Minerva at Rome, in which he was detained, and where he was buried. An inscription was placed over his tomb by order of Gregory XIII., in which he was described as a prelate "illustrious for his birth, his life, his doctrine, his preaching, and his charity." Llorente gives a copious abstract of this celebrated trial in chapters 32, 33, and 34 of his 'History of the Inquisition.'

Pope Paul III., alarmed at the progress of the doctrines of the Reformation, with the consent of Charles V. sent inquisitorial commissioners to the various states and provinces of Italy to try heretics; but they were instructed to proceed according to the usual form of the ecclesiastical courts, the depositions and names of the witnesses were to be communicated to the accused, and sentence of condemnation was not accompanied by confiscation; in short their powers were very different from those of the Spanish Inquisition. The Spanish viceroy of Naples, Don Pedro de Toledo, applied to the pope for an inquisitorial commissioner with a brief to proceed against persons suspected of heresy, but the Neapolitans, who were acquainted with the severities of the Spanish Inquisition, revolted, and, after much bloodshed, Charles V. promised that no Inquisition should be established in the kingdom of Naples, and that cases of heresy should be tried, as before, by the ordinary episcopal courts. These occurrences took place in 1546-7, and the Neapolitans, the better to secure themselves against the dreaded tribunal, established a court whose office it was to watch against any attempt to introduce the same under any shape—a kind of inquisition against the Inquisition. This court, which continued to exist till the French invasion of 1799, was styled "Tribunale contro quello del Sant Uffizio," and was composed of deputies, chiefly noblemen chosen by the different Seggi into which the Neapolitan nobility was classed. To the Neapolitan character, mercurial and communicative, the secret and mysterious proceedings of the Inquisition were peculiarly obnoxious.

Philip II. wished to introduce the Spanish Inquisition into the duchy of Milan, but the towns of Lombardy sent deputies to the council of Trent to remonstrate against it, and the Milanese and other Italian bishops wrote to the pope and to Cardinal Borromeo, representing that the Inquisition of Spain acted in the dark, in an arbitrary manner, and with strange and fearful forms of proceeding, that it took away the jurisdiction from the bishops, that it showed itself more a rival than a subject to the papal see, that it had repeatedly refused to send a copy of its trials to Rome, and that if it were introduced into Italy, the Italian prelates, having its terrors before their eyes, would become estranged from the holy see. The pope, being easily persuaded by these reasons, interposed with King Philip, saying that if required he would, after consulting with the bishops of Lombardy, himself send inquisitorial commissioners from Rome, who should proceed not according to the Spanish form, but according to the canon law, and without prejudice to the episcopal authority. Thus the Spanish Inquisition was not introduced into Milan or into any other Italian state, with the exception of Sicily, which was an old dependency of the crown of Aragon.

The court of the Inquisition, as it was established in the 16th century, in Tuscany, Venice, Milan, Parma, and other Italian states, consisted of one inquisitor, sent from Rome, with assessors approved by the sovereign of the respective states, who appointed deputies or commissioners to attend the trials and report to him. The sentences of the court were subject to the sanction of the temporal sovereign.

The republic of Venice showed itself the most jealous of its sovereign rights in this particular. A series of statutes were issued at various times by the senate to regulate the proceedings of the inquisitors, which are given by Paolo Sarpi, in his 'History of the Venetian Inquisition,' and by Limborch, b. i., ch. 17. By a concordat with Pope Julius III., 1551, it was decreed that three senators were to attend all the proceedings and judgments of the Inquisition in the city of Venice, and although they took no part in the trial, they had the right to suspend the execution of the sentence and report to the senate. In the provincial towns lay magistrates were appointed to perform the same duty in the respective courts of the Inquisition. The Inquisition could not molest Jews or other unbelievers, or Greeks living under the protection of the republic. It could not take cognisance of cases of blasphemy or polygamy—which belonged to the secular jurisdiction—nor of witchcraft, nor of minor infractions of discipline, such as eating or selling of meat on Fridays, &c. Numerous other checks are provided by the same statutes. In short, although the Venetian senate was obliged by prudential reasons to admit the Inquisition within its territories, it took care to render it as inoffensive as possible. The famous tribunal of the state Inquisition, was entirely a political institution of the Venetian aristocracy, and must not be confounded with the ecclesiastical Inquisition.

In Tuscany the grand-dukes Medici had provided that deputies appointed by themselves should attend the trials of the inquisitorial court, and should report to them, and that no sentence should be executed without their sanction. But in the year 1566, Pope Pius V., a zealous promoter of the Inquisition, demanded of the Grand-duke Cosmo I. the person of Pietro Carnesecchi, a man of some rank and learning, and well affected to his sovereign, but who had publicly adopted several tenets of the Protestant Reformers. Cosmo gave him up to the officers of Rome, but at the same time wrote earnestly to the pope to save him. Pius was inclined to spare his life, if Carnesecchi had shown signs of repentance, but he boldly persisted in his opinions, and in August, 1567, he was convicted by the Roman Inquisition of thirty-four heretical tenets, and condemned to death. The grand-duke again wrote in his behalf, and the pope suspended the execution for ten days, promising to spare his life on condition that Carnesecchi should abjure his tenets, and he sent him a friar to exhort him to do so. But Carnesecchi remained firm: he argued with the monk, and wanted to gain him over to his own opinions. He was publicly beheaded at Rome, and afterwards burnt. In the following century Galileo was summoned from Florence to Rome, where, however, he was treated with considerable lenity, and after a verbal abjuration and a few months' confinement, he was allowed to return to Florence. The executions in Tuscany in consequence of sentences of the Inquisition were comparatively few. The tribunal continued to exist in Tuscany till the reign of Leopold of Austria, who began by curtailing its jurisdiction, took away its "sbirri," or bailiffs, gave the censorship of books to a lay magistrate, and at last abolished the tribunal altogether in 1787. About the same time it was suppressed at Milan by the Emperor Joseph II. In 1769 the Duke of Parma abolished it in his territories.

Pope Paul III. founded at Rome, by a bull dated April, 1543, the Congregation of the Holy Office, consisting of six cardinals, who were styled "inquisitors-general of the faith," who had the superintendance over all other inquisitors, and he gave them full authority to proceed, without the concurrence of the ordinaries or bishops, against all heretics or persons suspected of heresy, to punish them, confiscate their property, to degrade and deliver to the secular courts all clerical offenders, to call in if required the assistance of the secular arm, to appoint inquisitors with such powers as they thought proper, to appoint fiscal attorneys, notaries, and other officials, and to hear and decide on appeals from the judgment of other inquisitors. The pope, however, declared that by this bull he did not intend to make any alteration in the privileges of the Spanish Inquisition as then established.

In 1564 Pope Pius IV. confirmed and extended the powers of the Roman Inquisition, which, however, were resisted in the kingdom of France. In that kingdom there was no regular tribunal of the Inquisition. The Cardinal de Lorraine, under Henri II., had indeed appointed delegated inquisitors who acted as extraordinary judges in the trials of the Huguenots, but their jurisdiction was not exclusive, as the parliament also took cognisance of the crime of heresy, besides which the king appointed special commissioners for the same purpose. ('Histoire du Parlement de Paris,' ch. 21.) But the authority of the Inquisition was totally abolished in France as soon as tolerance was established by the Edit de Nantes under Henri IV., which allowed the Protestants the exercise of their religion, for tolerance and the Inquisition could not possibly exist together; and although Louis XIV. afterwards revoked that edict and persecuted the Protestants, he did it by means of the secular power, and took care not to allow the introduction into his kingdom of an ecclesiastical tribunal which would encroach upon his own sovereign authority. But he advised his grandson Philip V., whom he placed on the throne of Spain, to maintain the Inquisition as a means of ensuring the tranquillity of that kingdom.

Sixtus V. in 1588, having distributed the cardinals into fifteen congregations or boards, made that which was styled "Holy Roman and Universal Inquisition" to consist of twelve cardinals with several prelates as assessors, including the Master of the sacred palace, several monks with the title of "consultors," besides other clergymen and lawyers called "qualificators," whose business it was to prepare the cases. This is the Inquisition which still subsists at Rome, but its jurisdiction does not extend beyond the limits of the Papal States, and it is generally understood that its powers are exercised with considerable leniency and caution. Pius VII., after his restoration, is said to have abolished the use of the torture. The Roman Inquisition watches more particularly over the conduct of the clergy, and has also the censorship of the press and of the introduction of foreign works. The territory subject to the dominion of the pope is now the only country in which the tribunal of the Holy Office still remains.

In Germany and in Poland, the Inquisition has long since ceased to exist. In Spain it was suppressed, first by a decree of Napoleon, dated Chamartin, 4 December, 1808, as encroaching upon the rights of the sovereign, "attentoire à la souveraineté;" and on the 12th February, 1813, the extraordinary Cortes of Spain assembled at Cadiz definitively suppressed the Inquisition, as being incompatible with the new political constitution of the monarchy. At the same time they restored to the bishops the exercise of the ecclesiastical jurisdiction in cases of heresy. Ferdinand VII., after his restoration, re-established the Inquisition by an ordinance of the 21st July, 1814, and appointed the bishop of Almeria inquisitor-general. In this act Ferdinand stated to the people that one of his objects in re-establishing the Inquisition was "to repress the mischief occasioned to the national faith by the presence of the foreign troops which were not Catholic," including of course his allies the English, who had been the chief means of restoring him to the throne. It continued in Spain till the Revolution of 1820, when it was again suppressed by the Cortes. During these five years of its re-establishment, many persons were arrested, but none appear to have been put to death in consequence of its judgments. When Ferdinand, in 1823, a second time overthrew the constitution, he did not re-establish the Inquisition. In Portugal, the Inquisition, which was likewise abolished by the Cortes, has not been restored.

Various and often exaggerated accounts have been published of the number of persons put to death by the Spanish Inquisition during the three centuries of its existence. Llorente, who wrote with calmness and had access to the archives of the tribunal, gives an approximate estimate of the number executed under each inquisitor-general, from which it results that the total amount in Spain is about 32,000 persons burnt, either alive or after being strangled, 17,000 burnt in effigy, and 291,000 condemned to various terms of imprisonment, to the galleys, or subjected to other penalties. During the eighteen years of Torquemada's inquisitorship alone, about 8800 persons were burnt. This calculation does not include the Spanish colonies, nor the islands of Sicily and Sardinia, which were long subject to the Spanish Inquisition. It is impossible to ascertain the amount of the victims of the Inquisition in these as well as in other countries of Europe. The last person burnt by the sentence of the Inquisition in Spain was a woman accused of having formed a contract with the devil. She was burnt at Seville, on the 7th of November, 1781. The three last inquisitors-general, from 1783 to 1808, did not sentence any one to death.

In examining the history of the Inquisition under its various forms two things ought to be carefully distinguished; the principle and the practice of that remarkable institution. The fundamental principle of the Inquisition is, that heresy, that is to say, dissent from the tenets of the Roman church, is a heinous crime, and liable to both spiritual and temporal punishment. This principle however is not peculiar to the Inquisition: it is that of the canon law, and it has the countenance of the Roman law in several constitutions of the early Christian emperors. In every country therefore in which the canon law has civil or temporal force, the principle subsists, although it may lie dormant. A subject of such a country who should openly dissent from the established Church is liable to prosecution by the episcopal or the secular courts. This is still the case in several states of Italy, and even in Spain and Portugal under their new constitutional governments, at least until a new code shall be enacted. It must not be forgotten that the Inquisition was established in Spain while the Cortes of Aragon and Castile were still in full vigour. The minister of justice stated in the Spanish Cortes that laws were still in force by which persons, dying in a state of heresy, cannot bequeath their property. It is not therefore sufficient for the Inquisition to be abolished in a country, in order to ensure liberty of conscience; it is not even sufficient for this purpose to establish a representative or republican government, as long as the canon law remains in force and the majority of the people do not tolerate dissent. In the small democracies of the forest cantons of Switzerland, which are exclusively Roman Catholic, no dissent from the church is allowed, and persons accused of heresy are severely punished or obliged to emigrate.

In speaking of religious liberty, people are apt to confound three things very distinct, such as toleration, liberty of conscience or of opinion, and full religious liberty. Toleration properly applies to foreigners who profess a different faith from that established in the country which they come to visit or inhabit for a time, and who are tolerated, that is to say, allowed to remain unmolested, and in some cases are permitted to have chapels of their own communion. This is now the case in almost every European country, at least with regard to particular Christian communions and to the Jews. The Lutherans and Calvinists have chapels in almost every Roman Catholic state. But this toleration is not a legal right; it is only granted during pleasure to certain nations and sects, and it applies only to foreigners and by no means to natives. Even during the rule of the Inquisition in Spain, English, Dutch, and other Protestant merchants were allowed to reside in the seaport towns, but only so long as they gave no scandal or offence to the Roman Catholic faith, and their position was therefore extremely delicate and insecure.

Liberty of conscience applies to natives as well as foreigners, and in the country where it is recognised, no one can be molested for his religious opinions or private religious practice. But the law regulates whether and under what conditions chapels or places of religious worship may be opened which dissent from the established church of the country. Much is left to the discretionary power of the executive. Thus in France, wherever there are in a town a certain number of Lutherans or Calvinists, they are allowed to have a place of religious worship, subject to certain regulations of the local authorities. Liberty of conscience is only found in countries where a considerable part of the population dissent from the established church; it does not exist in countries exclusively Roman Catholic. All the Protestant states of Europe allow liberty of conscience.

Full religious liberty is said to exist when not only every man may hold what opinions he pleases, but when every Christian sect may openly profess its faith and perform publicly its rites; and this not by especial permission, but as a matter of legal right. This is the case at present only in England and its colonies, and in the United States of North America. But even those countries cannot be said to have unlimited religious liberty, for this would mean that any one might set up any form of worship that he pleased. Now it cannot be believed that Fetish or other pagan rites would be publicly allowed in England or America. Therefore the religious liberty of England and America can only be said to extend to the various Christian and Jewish communions. And indeed it is questionable whether religious liberty in its full unlimited extent could exist in any orderly community of which the majority believe in any religion whatever; for what would be called liberty by some, would appear offence and scandal to the rest, or contravene the common law of the land: as in the case of the Mormons, were they openly to inculcate the doctrine of polygamy. Besides which the danger of proselytism must necessarily complicate the question still more. Mohammedans tolerate Christians and Jews, but will not allow any one to apostatise from the Koran.

In the case however of countries in which penal statutes exist against heretics, it is still an important question how and when and by whom those statutes are to be enforced. We have seen how the Inquisition did enforce them, and the general opinion of Europe, not merely of Protestant but of Roman Catholic Europe, has reprobated and rejected its practice. The secular power has now taken into its own hands criminal jurisdiction in all its branches in every European state, with the single exception of the Papal State, where, the government being in the hands of ecclesiastics, the jurisdiction of the canon law is kept distinct from that of the civil law, and has its own courts, of which that of the Inquisition is the principal.

It is an error to suppose that intolerance is peculiar to the Roman Catholic church; all churches and religions, Jews, Mohammedans, and heathens, Arians and orthodox, Greeks, Latins, and Protestants—all have persecuted in turn; but no other church or sect ever invented or enforced for centuries a permanent system of persecution that can be in any respect compared with that of the Inquisition.

INSANITY, in Law. [Lunacy.]

INSANITY, mental alienation, lunacy, "folie" of Esquirol, &c. Of the various ills to which man is subject none are more dreaded, and few so little understood, as that which involves the loss of his intellect. Nor can we wonder at our ignorance of the nature of this malady when we remember what mystery hangs over the workings of the mind in its healthy state. But even while our knowledge of the nature of the mind and its operations, and therefore of the exact condition on which insanity depends, remains so limited, much, it is to be hoped, may be done towards alleviating the miseries which mental disease induces by investigating the causes which influence its prevalence, by inquiring into the best mode of restoring the mind to its healthy condition, and lastly, by learning to distinguish between those slight forms of mental disorder which amount to scarcely more than eccentricity or hypochondriacal fancies, and the more important states of disturbance of the intellect which render the subjects of them dangerous to themselves or others, and justify their seclusion from society and confinement in a lunatic asylum.

After a few words relative to the history of insanity, we shall consider its varieties and the characters which each presents, its causes, nature, and the definitions proposed to characterise it, the means of recognising it, and lastly, the mode of treatment.

It is probable that many of the unfortunate persons who are described in the Old and New Testament as possessed by evil spirits were the subjects of insanity. The same may also be said of the soothsayers and ecstatic priestesses of Egypt and Greece. In later times the dependence of insanity on a diseased state of the mind, or rather of its seat and instrument, the brain, has been generally recognised, but the sense of horror originally excited by the idea of the possession by a demon still influences in some degree the feelings with which the insane are regarded. But it is gratifying to find, that, with the extension of real knowledge, views at the same time more philosophic and more humane are beginning to be adopted in relation to lunacy.

The variety of the forms of insanity is almost endless, but they may conveniently for the purpose of description be collected under the following heads:—1. Disorders of the feelings and propensities. 2. Delusions or hallucinations. 3. General derangement of the reasoning faculties. 4. Mixed forms, in which two or more of the preceding are combined; and 5, the state of imbecility or fatuity in which other kinds of mental disorder frequently terminate.

1. The first principal form which we have indicated constitutes what is termed "moral insanity" by Dr. Prichard, who describes it as "consisting in a morbid perversion of the feelings, affections, and active powers, without any illusion or erroneous conviction impressed upon the understanding; sometimes co-existing with an apparently unimpaired state of the intellectual faculties." The character of the affection varies with the degree in which the different feelings are affected: sometimes jealousy and suspicion are the prevailing passions, causing their subjects to shun their dearest relatives and to live in constant misery, though at the same time they are able to reason correctly on any topic, and at times confess that their suspicions are groundless. Other persons are tormented by a constant fear and apprehension of some undefined danger or misfortune; and with this there is often a feeling of despair, a settled melancholy, frequently of a religious character. This state of despondency (combined with delusions, one of the most frequent kinds of insanity) is at its commencement often in a considerable degree under control, and may be removed from time to time by the substitution of more cheerful feelings; but if the circumstances to which the individual is subjected be of a nature to depress or alarm, it becomes so aggravated as to lead to a loathing of existence and to suicide. The states which we have considered are generally marked by depression, but they are not unfrequently interrupted by fits of violence and preternatural excitement of short duration. In other cases this last state chiefly characterises the disease. There is then a want of self-government; the expressions are unguarded and the conduct violent. M. Pinel records a characteristic instance of this, which he terms "emportement maniaque sans delire." It is a good example of moral insanity unattended with derangement of the intellect. "A youth, the only son of a weak and indulgent mother, was the subject of uncontrolled caprice and passion. He was excited to acts of fury by any kind of opposition or remonstrance; he put to death a dog, horse, or any other animal which offended him; and excited broils in every public meeting which he joined. But when not led by his passion he enjoyed sound judgment, was fully competent to discharge all his duties, and was humane. At length he threw a woman, who had offended him, into a well, was prosecuted, and condemned to perpetual confinement in the lunatic asylum Bicêtre." An inordinate degree of pride and vanity is often the prevailing characteristic of the feelings of a disordered mind; and it is generally attended with some delusion. A propensity to mischief, the destruction of all surrounding objects, is not uncommonly displayed by the insane; another degree of the same affection is the impulse to the destruction of life. Persons affected with this morbid excess of the destructive propensity have without doubt frequently suffered the punishment due to wilful murder; many persons have been known to complain of the impulse they felt to kill, and have even begged to be confined lest they should injure others. The propensity to theft also sometimes constitutes a marked feature of insanity. Dr. Prichard mentions having seen a lunatic who would only eat when he had stolen food, and whose keeper made it a constant practice to put into some corner within his reach various articles intended for his sustenance, in order that he might take them furtively. This propensity to steal is well known to have brought disgrace on members of rich and honourable families. It is probable that in many such cases there is an uncontrollable impulse to the act, independent of any anticipation of pleasure from the subsequent possession. An excess of the sexual feeling, from a want of control over the expressions, is occasionally a source of great misery. A female modest at other times will in a state of insanity use indecent language and by her conduct discover the grossest desires.

Though we have thus described disordered states of some of the feelings and propensities as varieties of "moral insanity," it must be remembered that generally the prevalence of any of these feelings in a morbid state is attended with some delusion or disorder of the intellectual faculties; while on the other hand it is exceedingly rare to meet with instances of delusion or of general insanity with a perfectly calm and natural state of the affections; when there is not a marked derangement or excited state of any one feeling or propensity in such cases, there is a strange perverseness of temper and disposition. The modification of madness which occurs in old people, and is designated "senile madness" by Dr. Burrows, who has accurately described it, is a species of moral insanity. The moral feelings are perverted, and some of the passions in a state of excitement. "The pious," says Dr. Burrows, "become impious; the content and happy, discontented and miserable; the prudent and economical, imprudent and ridiculously profuse; the liberal, penurious; the sober, drunken." Passions which had long been dormant resume their sway, and cast shame mingled with pity over the years of declining age.

2. The term monomania has been proposed by M. Esquirol, and adopted by most writers on mental disorders, to designate those cases of insanity in which the mind is occupied by some illusion or erroneous conviction, the individual still retaining the power of reasoning correctly on matters unconnected with the subject of his delusion. The word "melancholia" has been used in the same sense, which has given rise to the erroneous notion that insanity of this kind is necessarily of a gloomy character. It is rarely that the mind of the monomaniac is otherwise perfectly sound; there is generally combined with the delusion a morbid state of the moral feelings, and in many instances a great weakness of the reasoning faculty. The subject of the delusion is very various. It may have reference to the condition of the individual's own person; thus, some fancy that they have lost their head, others that their legs are not their own, but belong to some other person, others again that they have the devil or some animal within them, that they are dead, or that they are changed to some other form, &c. Monomaniacs subjects of the last delusion are thus described by Pope,—

> "Unnumbered throngs on every side are seen,
> Of bodies changed to various forms by spleen;
> Here living tea-pots stand, one arm held out,
> One bent; the handle this, and that the spout;
> A pipkin there, like Homer's tripod walks;
> Here sighs a jar, and there a goose-pie talks."

It is probable that in many cases of delusion regarding the condition of the body there is some morbid state of the nerves, causing a sensation which excites in a mind prone to insanity an idea which the reason is unable to correct. Another kind of delusion is that which characterises the "demonomania" of some writers. It consists in a belief in the presence of invisible beings whom the lunatic sees, hears, and converses with. Religious delusions are frequently of this character: the maniac sees and communes with the Almighty or with angels. Such ideas, being very often combined with despondency, lead to suicide. Others who are subjects of such delusions fancy themselves constantly followed by some person who has the purpose of injuring them. A third kind of delusion refers to unreal events which the individuals believe to have occurred, or consists in a belief in some absurdity which has no foundation except in the patient's imagination. Such a monomaniac was the gentleman who thought he had been confined in a castle, and corresponded with a princess by writing letters in cherry-juice. The delusions which most frequently take possession of the thoughts of the proud or vain madman are referrible to the head of those which arise from abstract ideas conceived in the mind being mistaken for realities. An ambitious dreamer may for a moment imagine himself a king, but it is only a lunatic who fails soon to perceive that he is such only in his own thoughts.

There is generally some connection to be traced between the nature of the illusion and the former occupation of the monomaniac, or the ideas which have chiefly engaged his mind. Thus a butcher is said to have fancied that he had a leg of mutton hanging from his nose; a youth, the son of an attorney, fancied himself suspected of a horrible crime, and that the officers of justice were following him; persons who have had their thoughts much directed to religious subjects imagine when they become insane that they have received a charge from the Almighty; that they are persecuted by the devil, &c., &c.

3. General derangement of the intellect presents many varieties and degrees; but the distinguishing character is that the faculties of the mind generally are disordered; the patient will not speak on any subject long without betraying the defect of his reasoning power. This will in one person merely lead to strange irrational conduct and conversation—its necessary consequences; in another it will be attended with loud and violent raving (mania); in a third there will be singing, and a gay cheerful air; while a fourth case will be characterised by a low muttering incoherence. This general insanity is most frequently attended with disturbance of the bodily health. The symptoms of mental excitement frequently increase in violence for a short time, then gradually subside into a more quiet state, which too often terminates in mental imbecility.

4. The mixed forms of madness are by far the most frequent. Moral insanity, the disturbance of the moral feelings and propensities, is generally attended with some degree of weakness of the reasoning powers, or with some delusion. The general derangement of intellect has combined with it an excited state of some of the feelings; and monomania in the pure form, a mental delusion without further disorder of intellect, is very rare.

5. The duration of insanity has no certain limits; the attack may last but a few weeks, or it may continue many years. It is not uncommon to meet in lunatic asylums with persons who have been insane twenty or thirty years. When the disordered state of the mind is thus protracted, it usually terminates in loss of the intellectual faculties. The state of imbecility, dementia, or fatuity, which then succeeds, has many degrees. It commences by the loss of memory, particularly for more recent events; the mind receives impressions and perceives them, but the faculty of retaining them seems to be lost. It is this state which so frequently attends the advance of years, and gives warning of approaching decay, when the mind is otherwise sane. In the latter instance the faculties are exercised in a sound manner when the attention is roused; but frequently the words which were spoken but a few minutes previously are forgotten, though the memory for the events of youth is quite distinct. In a second degree of imbecility the power of directing the thoughts is lost; ideas come and go without order and independently of the will; questions are still heard and attempts are made to reply to them, but before the answer is half completed the train of thought is lost, and the mind and tongue wander to other subjects. In proportion as the mind becomes more and more weakened the external senses also become deadened; there is a carelessness of all that is going on around; life is reduced to the state of that of brute animals; the instincts alone guide the actions. The features are void of expression, the countenance vacant, the eyes wandering. At last even the instincts are lost; the miserable creatures seem almost unconscious of life; careless of the calls and wants of nature, they sit or lie motionless in one position, and frequently lose even the use of their limbs.

Disease in the brain may thus go on to the abolition of all the functions by which mind is manifested, without interfering with those other functions of the body on which mere existence depends. Insanity cannot be regarded as a very fatal disease. Of the lunatics at the asylum Bicêtre in the year 1822, one patient had been there 56 years; 3 had been confined upwards of 40 years; 21 more than 30 years; 50 upwards of 20 years; and 107 more than 10 years. Of those in Salpetrière seven cases had been admitted from 50 to 57 years. It is difficult to ascertain the proportional number of recoveries from insanity, so different are the statements made by different writers. While some authors have reported the cure of nearly 5 in 6 cases, others have estimated the proportion cured as less than 5 in 10; some have stated it to be as low as 5 in 15. The chance of recovery, however, varies very much according as the insanity is complicated or not with other disease; it is also influenced by the form of the disease, the period of its course, the age, sex, and constitution of the patient. Of the diseases which occasionally complicate insanity, epilepsy and paralysis are the most important. Whether paralysis affect the motion of the limbs or the speech only, the case is generally considered hopeless. The complication with true epilepsy, not mere convulsion from temporary cerebral excitement, is nearly equally unfavourable. It appears that the general derangement of the intellect is more curable than monomania, more especially in men. The state of imbecility is almost certainly incurable. The period of the disease at which it is brought under treatment has a very important influence on the chance of recovery. Of those who enter asylums soon after the commencement of the malady, 7 out of 8, or even 9 out of 10, recover; while after the third year the probable proportion of cured is not more than 1 in 30. The mean duration of cases terminating favourably seems to be from 5 to 10 months. The age most favourable for recovery from insanity is the period from the 20th to the 30th year; few recover after the 50th. Insanity is generally more curable in women than men. There is more hope of recovery when some secretion of the body is suspended which may be restored by medicine, or when a critical period, such as that of the appearance or cessation of the catamenia in women, is at hand; at such periods as those last referred to insanity has ceased after having persisted for many years.

During the period of convalescence there is great liability to relapse, but this diminishes with the increasing length of time during which the patient manifests no symptoms of unsoundness of mind. The more complete the recovery, the more likely it is to be permanent; if the judgment be strong, and the feelings neither depressed nor irritable, relapse is much less to be feared.

Causes.—Some individuals appear to be so prone to insanity that very slight causes are sufficient to induce it in them; or it is probable indeed that there is always some peculiarity in the constitution predisposing to it, since the apparent causes do not differ from those which, acting on other persons, produce other diseases and not insanity. Be this as it may, a tendency to mental and other cerebral afflictions is often observed to prevail in families, and to be transmitted from parents to offspring. An attack of insanity not only produces such a change in the system as to render it more prone to the disease than before, but the condition of the body, or rather of the brain, thus induced, may be transmitted to the children. This fact is so well known that it is unnecessary to insist further upon it. The hereditary predisposition is said to be stronger when both parents have been insane. A remarkable circumstance relating to the hereditary transmission of insanity is that the form of the disease which affects different individuals of a family is often the same, and that it attacks them about the same age. It is an opinion generally adopted that intermarriage in families gives rise to the predisposition to mental disorder, as it certainly does to weakness of body and mind. Intermarriage must tend to strengthen or maintain original peculiarities of constitution, and therefore any predisposition to disease which may exist. It is almost impossible to ascertain the proportion of cases connected with hereditary predisposition, so much is it the desire and interest of families to conceal such a circumstance.

The proportion in which the sexes are affected with insanity varies very much in different parts of the world. In Great Britain and Ireland the proportions of males to females insane is stated to be as

13 to 12. In Italy also the number of male lunatics is greater than that of the females. But in France there are more females than males insane, in the proportion of 14 to 11. Calculating from statistical accounts derived from different parts of the globe, M. Esquirol found that the proportion of men to women insane is nearly as 37 to 38. The concurrent testimony of French and English physicians tends to show that the number of the male sex affected with lunacy, as compared with the female sex, is greater in the higher than in the lower ranks of society.

Insanity is rare, though it sometimes occurs, before the period of puberty. It is from the age of 14 to 17, when a great change is taking place in the system, and when the passions begin to be more active and more liable to excitement, that insanity becomes frequent. The liability to the disease increases up to the age of 40; and although the absolute number of persons in lunatic asylums of different ages from 40 upwards becomes less and less, yet if we take into consideration that the number of persons living at the more advanced ages is also much less, we shall be led to infer, not that the liability to insanity diminishes in old age, but, on the contrary, that it rapidly increases. An excellent paper by M. Esquirol on the statistics of insanity, in which the number of insane persons at the different ages is compared with the population of the same ages, shows this in a very striking manner.

Of the causes which excite the development of insanity in individuals predisposed to it, those which act on the mind are the most efficient. It will most frequently be found that immediately before the attack the patient has suffered some severe vexation or disappointment from family troubles, pecuniary embarrassment, &c. We have seen that insanity rarely shows itself before the age in which the mind is susceptible of strong feelings, and in which the passions are excited by strong interests. A calculation made by M. Pinel represented the proportion of cases produced by moral causes, as compared with those due to physical causes, to be, in a space of five years, as 464 to 219. In one of the largest of our English asylums the proportion of cases ascertained to have been excited by moral causes was, during the years 1831 to 1836 inclusive, 431; those ascribed to physical causes, 291. The proportional influence of moral causes is, however, probably much greater than is here indicated; for in 454 cases admitted into the asylum to which we refer during the six years, no cause was assigned, and of these it must be presumed that a large number were due to moral influence. It is the slow and constant action of the depressing passions that is most instrumental in disordering the mental faculties; the violent and sudden passions much less frequently have this effect. Of the 431 cases produced by moral causes in the asylum from which we derive these facts, 289 were ascribed to trouble of mind from pecuniary distress or family disasters, grief, jealousy, disappointment, &c. Religious impressions are frequently instrumental in exciting complete derangement of the intellect in minds already sensitive and weak; 43 cases out of the 431 were traced to religious excitement. The other causes acting directly on the mind, which are more or less active in exciting insanity, are disappointed love (a not unfrequent cause in young females), fright (also acting chiefly on females), excessive study, and political excitement, which during the Revolution and succeeding years was a productive source of mental alienation in France; but cases from that cause are now comparatively rare even in that country, and of upwards of 1200 cases admitted during six years into an English asylum, two only were traced to political causes.

Of the physical causes of insanity those connected with circumstances which affect females only afford the greatest number of cases; 62 out of the 291 cases of insanity from physical causes were connected with parturition or nursing. Insanity occurring under such circumstances is termed puerperal mania, the frequency of which is not easily explained. Retardation of the appearance of the menses and their suppression are likewise occasional causes of insanity in females. The frequent dependence of mental disorder on intemperance, particularly in men, is a fact demanding much attention. Drunkenness is unfortunately a prevailing vice in England, and accordingly we find a much larger number of insane from that cause in the pauper lunatic asylums of this country than in those of France, where the abuse of intoxicating liquors is less general. Next to intemperance, the causes which act more directly on the brain itself, and give rise to inflammation or disturbance of the circulation in it, are the most influential in producing the predisposition to insanity, or in exciting it; such causes are blows on the head, fever, coup de soleil, &c. Epilepsy and, less frequently, apoplexy also lead to insanity. Lastly, any influences acting prejudicially on other parts of the body may indirectly affect the mental organ and disorder its operation.

Closely connected with the subject of the causes of insanity, and of equal importance, are the statistics of the disease. If we could ascertain all the important circumstances which accompany its greater or less prevalence in different countries, we might hope to be able to combat in some measure the evil, by adopting preventive measures. A general result, which appears to rest on correct information, is, that insanity is extremely rare in uncivilised nations, as among the natives of Africa and America. This cannot arise solely from passion less frequently disturbing their moral feeling and affections, though this is undoubtedly an influential circumstance. There seems to be an absence of the predisposition to many diseases among the uncivilised races. A less highly developed and less active condition of the brain may render it less prone to disease.

In Turkey, Spain, and Italy, insanity is comparatively less prevalent, if we may judge from the imperfect reports obtained from those countries, than in the more northern European nations and the United States of America. The proportion of lunatics to the population in England and France is, according to the calculations of Sir A. Halliday and M. Esquirol, about 1 to 1000. In Prussia the proportion, as stated by M. Jacobi, is about the same. But in Wales the proportion of insane to the population was estimated by Sir A. Halliday to be as high as 1 to 800, and in Scotland 1 to 574. In Norway too, a country somewhat similar in its physical character and in the condition of its inhabitants to Scotland, the estimate of the proportion of lunatics given by Dr. Holst is 1 to 551. A great and surprising difference is found to exist in the proportional number of insane in manufacturing and agricultural districts of England; the number being greater in the agricultural counties. This is an analogous fact to the prevalence of the disease in Wales and Scotland. There is certainly less call for the exertion of the intellectual faculties in the agricultural than in the manufacturing counties, and in Wales than in England; an explanation of the facts must therefore be sought in other circumstances. In the statistical calculations are included not merely the insane, but the idiotic from birth, and the excess in the number of unsound in mind in Wales, Scotland, and Norway, as compared with France and England, is due to the greater number of idiots, of which we can find some explanation in the hardships to which the poor of those mountainous and partly barren countries are exposed; idiotcy being a disease dependent on imperfect formation of the brain, and generally attended with other marks of an ill-developed organisation. The greater liability of the agricultural population of England to insanity is less easily accounted for. The much greater degree in which insanity presses on the lower than on the higher classes of society, is another important consideration. One cause of this is undoubtedly the much less check which is put upon the spreading of the disease by marriage with individuals whose families have the predisposition in the lower than in the higher classes. Another may be the deprivations to which parents, and particularly pregnant females, are exposed. A third is the prevalence of intemperance among the poor. The opinion has prevailed in France as well as in England, that insanity is on the increase, but the data on which this supposition is founded cannot be implicitly trusted, for the greater number and better management of lunatic asylums at the present day cause many more persons to be conveyed to them, and thus placed within the reach of statistical research; while formerly many lunatics were allowed to wander about as beggars; many from shame, or fear of the horrors of the asylum, were concealed in private families; and some, from ignorance, were punished as criminals.

The principal means of checking insanity, which the facts above detailed seem to suggest, are, 1, the prevention of the marriage of individuals predisposed by inheritance to the disease; 2, the improvement of the physical condition of the poor; 3, the encouragement of intellectual cultivation and amusements among the lower classes, as a means of checking intemperance and sensual indulgence generally; 4, a better education of the moral feelings in all classes of society, so as to discipline the passions and enable the mind to resist their disturbing influence.

Before entering on the consideration of the mode of detecting insanity, it will be necessary to inquire into the probable nature of the disease. We will first state the facts on which is founded the opinion that it is dependent on some disease in the brain. It is not requisite to offer any proof that the brain is, in the healthy state, the seat of the mental operations, the organ or instrument by which the mental principle, whatever it be, acts. Admitting this, we may naturally suppose that the cause which disturbs the functions of the mind has its seat in the same organ. Then again, although in many cases no change of structure can be found in the brain after death (which cannot surprise us if we remember the delicacy of the organ, and the slight change that would be sufficient to disorder its action), yet it is certain that morbid appearances are found much more frequently in the brain than in any other part of the body of the insane after death. The commencement of the disease is generally accompanied by pain and other symptoms of inflammation or vascular fulness of the head. In some cases we perceive a distinct connection between marked disease of the brain and insanity, as where the latter affection supervenes on epilepsy or apoplexy. The physical causes too are in many instances such as act directly on the brain; we allude to blows on the head, inflammation of the brain, coup de soleil, &c. Even the moral causes of insanity afford an argument in favour of the cerebral pathology of the disease; for the inordinate action of the brain which must attend the long continuance and great violence of a particular passion would be likely to excite diseased structure of the organ. The diseased states of other viscera, those of the abdomen for example, can only be regarded as consequences of the insanity, or as accidental complications, or if they stand at all in the relation of causes, as acting only through the medium of the brain.

It being thus premised that the brain is the seat of the disease, can we recognise any particular character in the disordered reasoning and feelings of the insane which will afford us a means of defining it, and enable us to distinguish it from other disturbed states of the mind and senses? Many writers, led by some observations of Mr. Locke, have said that "the insane reason correctly from erroneous premises." But this definition includes those only who are the subject of some delusion, while there are many lunatics who have lost the power of reasoning correctly, hence some authors have added to the above definition the sentence "or erroneously from correct premises." The definition, founded on Mr. Locke's remark, applies very well to the state of mind of many monomaniacs, who frequently act quite reasonably on the supposition of the subject of their delusion being a fact; it is in their believing what a sound man must perceive to be false that their insanity consists. Thus many persons under the influence of particular states of the brain or the senses of vision have seen spectres, but, not believing in their actual existence, were not mad. The belief in things inconsistent with the laws of nature, with the combined evidence of all our senses, or with other known facts, shows a want of reasoning power, or, according to Dr. Conolly, a want of "the comparing power;" the lunatic does not compare the evidence of one sense with that given by other senses, or with past impressions; if he did so, he would detect his error. A madman fancies his legs are made of butter, and accordingly protects them from the sun and external force; but if he used his senses of touch and sight, and compared their evidence with the sensation which excited the erroneous idea, or with the idea itself, he would perceive its falsity. There are, however, as we have said, many other cases in which, whether combined with delusions or not, there is a defect of the reasoning power, the degrees of which vary from the state of the persons who are regarded merely as somewhat silly, to that of the imbecile or fatuitous. There is, however, another less frequent form of insanity, which depends neither on reasoning from erroneous premises, nor on defect of the reasoning faculties; we allude to the state in which the moral feelings are so deranged or excited as to lead to acts which may be called insane, since the will has no longer the power of regulating them, and the individual cannot be looked upon as an accountable being. The definition adopted by Dr. Spurzheim and the phrenologists will include this last form of insanity. Insanity is by them stated to be "an aberration of any mental power (an intellectual faculty, a moral feeling, or a propensity), from the healthy state, with an inability on the part of the individual to discern its unhealthiness or to resist it."

In deciding what is and what is not insanity there will not be much difficulty if any illusion exist in the patient's mind, and its nature be known to the examiner; and when there is general derangement or defect of the reasoning powers, a careful examination will surely detect it. It is much more difficult to decide as to the existence of moral insanity when unattended with delusion or defect of the reasoning faculty, though the decision is here often of the greatest importance, as the honour or life of the individual depends upon it. No rules can be laid down for determining whether eccentric acts, or the commission of homicide, be the effect of an irresistible impulse or not; in all such cases however, the history, the dress, gestures, and manner of speaking, and the expression of the features of the individual, should be carefully attended to. In almost all insane persons there will moreover be found either symptoms of vascular excitement about the head, or an unhealthy state of the skin and of the different secretions.

There are however, as Dr. Conolly observes, two questions to be decided in every inquiry relative to the sanity of an individual. The first relates to the existence of unsoundness of mind; the second regards the treatment required, and especially the necessity of restraint, and the degree and nature of the restraint. With reference to the second question, the chief point to be considered is whether the patient be likely to injure his own person or that of others, or his own property or that of others. Medical treatment may be required in any case of insanity; but on the decision of the second question above indicated depends whether the patient shall be confined and deprived of control over his property. It is from confounding the question of the existence of madness with that of the necessity of confinement that so much injustice has been committed; to prove a man insane has been synonymous with condemning him to imprisonment. But though a man believe his legs are not his own, or that he was present at the destruction of Jerusalem, he may be a perfectly harmless and even useful member of society: shall he therefore be deprived of his liberty and of the management of his property merely on account of a single delusion? [LUNACY.]

The treatment of insanity resolves itself into the medical and the moral. The medical treatment indicated and required at the commencement of the disease consists chiefly in the attempt to reduce increased vascular excitement or slight inflammatory action. It is seldom that any violent antiphlogistic measures are required. The same treatment may be called for during the course of the disease if the symptoms of cerebral excitement or inflammation return. Sometimes want of sleep is the most marked symptom, and opiates are given with benefit. In the more chronic conditions of the disease the medical treatment is chiefly directed to the restoration and maintenance of a healthy state of all the functions of the body, particularly of the secretions. A strengthening diet is requisite in some cases; cleanliness, fresh air, and exercise in all. The best asylums afford the means of employment for the insane in the open air; but this important requisite is still neglected in some large public institutions.

The moral treatment is now recognised as an important part of the management of the insane. Formerly a lunatic was regarded with horror, as a being who had lost all relation to society, and was to be treated as a wild beast; he was confined in a gloomy filthy cell, was loaded with chains, and shut out from all influences which could cheer his mind or lead it from the subject of its delusion. The first step in the great amelioration which has taken place was effected by the efforts of M. Pinel in France, and the Quakers in England. The insane are now treated with humanity. The power of moral influences in restoring the healthy tone of the mind has been recognised as a principle, in carrying out which the chief means adopted are the following:—1. In many cases seclusion from society, chiefly with a view to remove the patient from the influence of the circumstances which produced the disorder, or which might keep up unhealthy trains of thought; but when the insanity is partial, consisting in a single delusion, this measure can scarcely be recommended, as it might, by shocking the mind, increase the malady. 2. Occupation and amusement of the mind in various ways, so as to divert the thoughts: this is an important circumstance in the treatment, though until the last few years little attended to. Everything calculated to remind the patient of his state should be avoided; the apparatus of confinement kept from his sight, and the appearance of all objects rendered as cheerful as possible. 3. The moral influence of the physician has a powerful effect on the mind of the insane; kindness will gain their confidence, while a firm though mild manner is often sufficient to restrain the most violent outbreaks of rage, and render other means of restraint unnecessary. Chains are now generally discarded from the apparatus of the lunatic asylum, and even strait waistcoats and straps are seldom required. But while measures of bodily restraint should be avoided as much as possible, it is a safe and imperative rule to remove hurtful weapons and means of mischief from the reach of the insane. All irritation of mind by threats, &c., should be avoided. 4. The convalescent should be separated from the other patients in the asylum. 5. The insane should be classified, so as to separate the quiet and timid from the noisy and violent.

In the preceding portion of this article we have not made *idiotcy* the subject of separate consideration. It is scarcely necessary to say that while *fatuity* is the state of defective intellect produced by disease late in life, *idiotcy* is the original want or deficiency of mental power. Just as the imbecility of old age has various degrees, so there are various degrees of idiotcy. One of the worst forms is that presented by the Cretins, the deformed and imperfectly organised idiots met with in the valleys of Switzerland. [CRETINS.] Idiotcy generally depends on congenital disease, but sometimes it is produced by diseases affecting the brain in very early infancy. The more remote causes are probably imperfect nourishment of the parents, or some noxious influences acting on the mother during pregnancy; the same hereditary predisposition which gives rise to insanity seems also sometimes to be productive of idiotcy. The form and size of the head in idiots may be quite natural; in many cases however it is large and deformed; in others remarkably small, particularly in the region of the forehead. The bones of the head are sometimes very thick; the brain itself disorganised, or its cavities distended with fluid. [HYDROCEPHALUS.]

(Prichard, Conolly, Burrows, and Haslam, *On Insanity*; Pinel, *Sur l'Aliénation mentale*; Esquirol, *Sur les Maladies mentales*; Georget, *Sur la Folie*; Heinroth, *Die Störungen des Seelenlebens*; Jacobi, *Sammlungen für die Heilkunde der Gemüthskrankheiten*; and Bucknill and Tuke, *Manual of Psychological Medicine.*)

INSCRIPTIONS (*Inscriptiones*), that is, records of public or private occurrences; of laws, decrees, and the like, engraved on stone, metal, and other hard substances, exhibited for public inspection. The custom of making inscriptions was far more general in the states of antiquity than in any modern country, as we see from the innumerable inscribed monuments which still exist in Persia, Egypt, Greece, Italy, and other countries subject to or colonised by the Greeks and Romans. A great number of inscriptions, especially those recording great events, laws, or decrees of the government, which it was important for every citizen to know, supplied to some extent the want of the art of printing. When, for example, the laws of the twelve tables at Rome were set up in public, this public exhibition was equivalent to their publication by means of the art of printing; for every Roman might go and read them, and, if he liked, take a copy of them for his private use. Previous to the invention of the art of printing, inscriptions set up in a public place were the most convenient means of giving publicity to that which it was necessary or useful for every citizen of the state to know. Inscriptions, therefore, are, next to the literature of the ancients, perhaps the most important sources from which we derive our knowledge of their public, religious, social, and private life, and their study is indispensable for those who desire to become intimately acquainted with the history of antiquity. For the history of the languages they are also of very great though not of equal importance. After the overthrow of the Roman empire in the west, inscriptions still continued to be made very frequently; but as the ignorance of the middle ages increased, and as all knowledge became more and more confined to the priesthood, the custom of making certain things known by means of inscriptions gradually fell into disuse, until the art of printing did away with it almost entirely.

In order to render inscriptions as permanent as possible, the ancients chose such materials as were least subject to destruction—namely, stone or metal. The stone most commonly used was marble cut in slabs, but sometimes inscriptions were engraved upon a flat surface of the unhewn rock. The most common metal was brass or bronze, though we have instances also of lead, tin, and gold being used. If we believe the accounts of the ancients, inscriptions were made even in the mythical ages (Herod., v. 59, &c.; Pausan., viii. 14, 4; ix. 11, 1); but such inscriptions existing in later times were probably forgeries, and we cannot suppose that inscriptions were made until the art of writing was pretty generally known.

We shall here pass over the arrow-headed inscriptions of Assyria [CUNEIFORM CHARACTERS], the hieroglyphics of Egypt [HIEROGLYPHICS], and the inscriptions of Etruria, Lycia, and other countries, and confine ourselves to those written in Greek and Latin.

Greek Inscriptions.—The earliest Greek inscriptions which we may safely take to have been genuine, but all of which have perished, were the lists of the victors in the Olympian games (Paus., iii. 21, 1; v. 4, 6, &c,), the records of the musical contests at Sicyon (Plutarch, 'De Mus.,' 3, 8), and the chronicle of the priestesses of Hera at Argos. The earliest among the extant inscriptions do not seem to have been made much before the year B.C. 580.

All inscriptions are composed either in prose or verse, but prose inscriptions form by far the greater number. The prose of the public documents is usually stiff, and their style is not unlike that of official documents of our own time. All Greek inscriptions are written in capital letters, and without any punctuation or separation of the several words, which often renders it difficult to read and understand them properly. Some of the earliest inscriptions are written, like the Hebrew, from the right to the left; others varied their lines, the first being written from the left to the right, and the next from the right to the left. In this manner, which is called Boustrophedon (*βουστροφηδὸν*), the laws of Solon were written, and some specimens are still extant. The method of later times was to write, like ourselves, from the left to the right. But besides these general distinctions, there occur a great variety, and some modifications of writing which are the result of mere fancy. Another important point which it is necessary to know before attempting to read Greek, and more especially Roman, inscriptions, are the abbreviations of names and words (*sigla*), which have been described and explained in several works, such as Nicolai, 'De Siglis Veterum,' Lugdun. 1703, 4to; Maffei, 'De Græcorum Siglis Lapidariis,' Verona, 1746; E. Corsini, 'Notæ Græcorum,' Florence, 1749, fol.; Placentinus, 'De Siglis Veterum Græcorum,' Rome, 1757, 4to; but the best work on the subject is Franz, 'Elementa Epigraphices Græcæ,' Berlin, 1840, 4to, which is at the same time a complete introduction to the study of Greek inscriptions.

Public or state documents were exhibited in Greece in certain places of great publicity, as the Acropolis at Athens, and sometimes whole walls were set apart for the purpose of receiving marble or metal slabs with inscriptions. Market-places and temples likewise served as repositories for inscriptions. When it was intended that an inscription should be understood by two different nations, it was written in the languages of both (*inscriptiones bilingues*), as in Greek and Assyrian (Herod., iv. 87), Greek and Phœnician (Gesenius, 'Monum. Phœnic.,' i., p. 93, &c.), Greek and Latin, Greek and Lycian (Grotefend, in the 'Transactions of the Royal Society,' iii. 2, p. 317, &c.), and Greek and Egyptian, as on the Rosetta stone in the British Museum.

The necessity of making collections of the most important inscriptions, such as contained public decrees, or interesting epigrammatic poems (of which many have found their way into the Greek Anthology), was felt by the Greeks themselves. The earliest collection we know of is that of Philochorus, under the title of Ἐπιγράμματα Ἀττικά; his example was followed by Polemon in a work *Περὶ τῶν κατὰ Πόλεις Ἐπιγραμμάτων*, and especially by Craterus in the important collection entitled Συναγωγὴ Ψηφισμάτων. Although public inscriptions were under the protection of the state, and although their violation was severely punished, we nevertheless know of several instances in which they were maliciously or frivolously destroyed or mutilated. In certain cases the state itself ordered the destruction of public documents, as when decrees were annulled or abolished. In times of war and in the destruction of towns innumerable inscriptions must have perished. Athens, as early as the time of the Persian wars, gives us an example of the destruction of public monuments, as pillars, and tombstones with inscriptions, for the purpose of building walls for the protection of the city. Still greater havoc was made by the early Christians among the ancient monuments, which were frequently used as building materials for all kinds of edifices; and if, in addition to all this, we consider the ravages of time and the destructive influence of rain and air, it is astonishing to see the immense number of inscriptions that have been preserved down to our own time.

The first modern writer who conceived the idea of making a collection of ancient inscriptions was Cyriacus of Ancona, who undertook, in 1435, a journey through Italy, Greece, and Asia Minor, and brought back a great number of inscriptions, which he collected in 3 vols. MS., which are still extant in the Barberini Library at Rome, and have often been used by subsequent collectors. After Cyriacus a long time elapsed, during which the attention of the learned was chiefly directed towards Roman inscriptions. Scipio Maffei, and after him J. Carcagni and T. M. Raponi, formed the plan of a complete collection of all inscriptions, but none of them were able to carry it into effect, and people were satisfied with books containing such inscriptions as their authors happened to meet with, or thought of particular interest. Works of this kind are:—Janus Gruter, 'Inscriptiones Antiquae totius Orbis Romani,' Heidelberg, 1602, 2 vols. fol.; 'Marmora Arundeliana' (also called 'Oxoniensia,' containing twenty-nine Greek and ten Latin inscriptions), edited by J. Selden, London, 1628, 4to, by Prideaux, Oxford, 1676, by Maittaire, London, 1732, and by Chandler, Oxford, 1763; Oct. Falconerius, 'Inscriptiones Athleticae Graecae et Latinae,' Rome, 1668, 4to, is the first attempt at a systematic collection; J. Spon, 'Itinerarium in Italiam, Illyricum, Graeciam, et Orientem,' Lugdun., 1678, 3 vols. 8vo; Thom. Reinesius, 'Syntagma Inscriptionum Antiquarum,' Lipsiae, 1682, fol.; W. Fleetwood, 'Inscriptionum Antiquarum Sylloge,' London, 1691, 8vo; R. Fabretti, 'Inscriptiones Antiquae,' Rome, 1699; A. van Dale, 'Dissertationes Antiquariæ et Marmoribus cum Romanis tum Graecis illustrandis inservientes,' Amsterdam, 1702, 8vo; A. F. Gori, 'Inscriptiones Antiquae Graecae et Romanae quae extant in Etruriae Urbibus,' Florence, 1727, 3 vols. fol.; L. A. Muratori, 'Novus Thesaurus Veterum Inscriptionum,' 1739, &c., 4 vols. fol., with a Supplement by S. Donatus, Lucca, 1765, &c., 2 vols. fol.; E. Corsini, 'Inscriptiones Atticae nunc primum e Maffei Schedis editae,' Florence, 1752, 4to. The material collected in these works was greatly enriched by the collections of inscriptions made by travellers, as Pococke, P. M. Paciaudi, Torremuzza, Passionei, Walpole, C. Vidua, and others. With the assistance of these further accessions, F. Osann began, in 1822, his 'Sylloge Inscriptionum Antiquarum Graecarum et Latinarum,' which was completed in ten fasciculi in folio, 1834; and F. G. Welcker published a smaller collection of metrical inscriptions, 'Sylloge Epigrammatum Graecorum ex Marmoribus et Libris collecta,' Bonn, 1828, 8vo.

But in the meantime the Berlin Academy had formed the plan of publishing a complete collection of all the known Greek inscriptions, of which A. Boeckh undertook the editorship. This great work bears the title, 'Corpus Inscriptionum Graecarum,' is in three huge folios (Berlin, 1828–53), and is by far the most complete collection of Greek inscriptions extant. They are arranged according to the countries and localities in which they were found; and in each particular where it is feasible, as in those of Athens, Boeckh has judiciously classified them into ten sections:—1. Acta senatus et populi, universitatum et collegiorum; 2. Tabulae Magistratuum; 3. Tituli Militares; 4. Magistratuum Catalogi; 5. Agonistica et Gymnastica; 6. Honores Imperatorum et aliorum ex domo Augusta et decreta imperatoria; 7. Tituli Honorarii; 8. Donariorum Tituli et Operum Publicorum; 9. Ordo Sacrorum, Termini, Defixiones Magicae, Supellex varia; 10. Monumenta privata, maxime sepulchralia. It is partly owing to the influence which Boeckh's 'Corpus Inscriptionum' exercised upon the scholars of our time, and partly to the political condition of Greece, that since the publication of the first volume of Boeckh's work a prodigious number of inscriptions have been brought to light by travellers, which were before unknown; all published up to 1852 have been incorporated in the 'Corpus Inscriptionum.' The principal among these subsequent works are:—Ph. Lebas, 'Inscriptions Grecques et Latines recueilles en Grèce,' Paris, 1835, &c.; Janssen, 'Musei Lugduno-Batavi Inscriptiones Graecae et Latinae,' Lugdun. Bat., 1842, 4to; L. Ross, 'Inscriptiones Graecae ineditae,' Naupliae, 1834–45, 4to; H. N. Ulrichs, 'Reisen und Forschungen in Griechenland,' Bremen, 1840, 8vo; L. Stephani, 'Reisen durch einige Gegenden des nördlichen Griechenlands,' Leipzig, 1843, 8vo; E. Curtius, 'Inscriptiones Atticae nuper repertae duodecim,' Berlin, 1843, 8vo; C. Keil, 'Sylloge Inscriptionum Boeoticarum,' Lips. 1847, 4to; the travels of Colonel Leake, Fellowes, and Hamilton: the work of Mr. Hamilton contains a large number of inscriptions from Asia Minor; and Letronne, 'Recueil des Inscriptions Grecques et Latines de l'Egypte,' 2 vols., Paris, 1842–48, 4to; and the Philological Journals of Germany, France, and England.

Latin Inscriptions.—These are not less numerous than those of Greece, and are found in great numbers at Rome, in Italy, and all the countries which were once subject to Rome. They embraced the same variety of subjects as the inscriptions in Greece, and if only the principal ones had been preserved the early constitution of Rome would be comparatively clear, whereas now there are a vast number of questions to which we can only answer by conjectures. Some of the Roman writers have, it is true, made use of the most important inscriptions for the early history of Rome, but not by any means to that extent which we could wish. The attention of Roman writers does not appear to have been so much directed towards this source of information as that of the Greeks, for there is no instance of any collection having ever been made by the Romans themselves, although some of their inscriptions were of the very highest importance in a constitutional as well as legal point of view. At the time of the overthrow of the Western Empire thousands of inscriptions must have perished, especially those engraved on metal, as the material excited the avarice of the Barbarians. But a great number was still preserved in Rome and Italy, which attracted the attention of the learned even in the early part of the middle ages.

The oldest collection of inscriptions found at Rome exists in the monastery of Einsiedeln: it is written on parchment, and probably belongs to the 10th or 11th century. It is printed in Mabillon

('Veterum Annal.,' p. 358, &c.). At the time of the revival of letters, the attention of the learned was chiefly directed towards the authors of antiquity, but ever since the 15th century attention has also been bestowed upon inscriptions. The man who first formed the idea of a comprehensive collection was the above-mentioned Cyriacus of Ancona, who undertook his travels at the request and the expense of Pope Nicholas I. The first printed collection of Latin inscriptions is that of Peutinger, who collected and published those which were found at Augsburg and in its neighbourhood on several folio leaves, under the title of 'Romanae Vetustatis Fragmenta in Augusta Vindelicorum et ejus Dioecesi,' Augsburg, 1505. Another collection, which is now extremely rare, was published by Laurentius Abstemius, at Fani in 1515, of which a second edition by F. Polyardu appeared in the same year. The collection published by the bookseller Mazocchi, at Rome, in 1520, in folio, under the title 'Epigrammata Antiqua Urbis Romae,' contains scarcely any other than sepulchral inscriptions.

After these collections of local inscriptions, B. Amantius and P. Appianus, supported by the liberal merchant Raimund von Fugger, published a general collection under the title of 'Inscriptiones Sacrosanctae Vetustatis,' Ingolstadt, 1534, fol. Soon after, the learned George Fabricius published a considerable collection of Latin inscriptions which he had made in his travels, and which had been communicated to him by his friends, in the second volume of his 'Roma,' Basle, 1550, reprinted in 1587, and at Helmstädt, 1660, fol. Martin Smetius of Bruges, during a stay of six years in Italy, made a very careful collection of inscriptions, which however were not published till after his death by Janus Douza, and with an auctarium by J. Lipsius, Lugdun.-Bat. 1588, fol. The work of Laurentius Schrader, 'Monumenta Italiae,' has one volume which contains only inscriptions which he had collected during his visits in Italy; they are arranged according to the towns in which they were found, but he does not distinguish between the earlier and later inscriptions, and he has some which are evidently not genuine. After that of Schrader followed that of Thom. Reinesius, which was mentioned above. A somewhat more complete and accurate collection of 4688 inscriptions was published by Fabretti under the title 'Inscriptionum Antiquarum, quae in Aedibus Paternis asservantur Explicatio et Additamentum,' Rome, 1699, fol. (some copies bear date of 1702, but this is only a bookseller's imposition).

But all the works here mentioned are eclipsed by the undertaking of Janus Gruterus, which was to contain all the inscriptions that had until then been made known. He took the work of Smetius as his foundation, and was actively assisted by Joseph Scaliger. The collection appeared under the title 'Inscriptiones Antiquæ totius Orbis Romani,' Heidelberg, 1603 and 1663, fol. J. G. Graevius afterwards undertook to edit a still more complete and corrected edition, but he did not live to complete his task, which fell into the hands of P. Burmann, who assisted by many other scholars, published the new edition of Gruter, under the title 'Inscriptiones Antiquae totius Orbis Romani, in absolutissimum Corpus redactae, olim auspiciis J. Scaligeri et M. Velseri, industria autem Jani Gruteri, nunc notis Marquardi Gudii emendatae, cura J. G. Graevii,' Amsterdam, 1707, fol. Marquard Gude, who had travelled in Italy, likewise prepared a collection of inscriptions for publication, which however was edited after his death by F. Hessel, Leovardiae, 1731, fol. This collection however contains many forgeries made by the notorious Ligorius. A collection of 2000 inscriptions which had been gathered by Doni, was published by Gori, 'T. B. Donii Inscriptiones Antiquae,' Florence, 1731, fol. In 1739, L. A. Muratori published his 'Novus Thesaurus Veterum Inscriptionum,' Milan, 4 vols. 4to., to which a supplement was added by S. Donatus in 2 vols., Lucca, 1765, &c. Among the collections of inscriptions published at a later time, the most important is the selection from all the known inscriptions which was published by J. C. Orelli, under the title 'Inscriptionum Latinarum selectarum amplissima Collectio ad illustrandum Romanae Antiquitatis Disciplinam accommodata, &c.; cum ineditis Hagenbuchii suisque Annotationibus,' Zürich, 1828, 2 vols. 8vo. This collection is extremely useful, especially as corrected and extended by the supplementary volume by G. Henzer, 1836; for the student should be warned that Orelli has not always published the inscriptions with that accuracy and exactness which are required in works of this kind. Another work of great value is the splendid collection of Neapolitan inscriptions made by T. Mommsen, 'Inscriptiones Regni Neapolitani Latinae,' fol. Lips. 1852. For the Latin inscriptions which are still continually being found in various parts of the world once subject to Rome, the student must consult the transactions of the various archæological societies formed in all parts of Europe, a chief object of which is the searching after, preserving, and publishing the Roman monuments existing in the particular districts in which those societies are formed. The number of Latin inscriptions now known amounts to considerably over 60,000.

Among the works to be consulted by those who wish to acquire a facility in reading and understanding Latin inscriptions, the following are of importance: Zaccaria, 'Instituzione Lapidaria,' Rome, 1770, and Venice, 1792; Morcelli, 'De Stilo Inscriptionum Latinarum Libri Tres,' Rome, 1781, and reprinted in his 'Opera Epigraphica,' Patavii, 1819, 5 vols. 8vo.; Kopp, 'Palaeographia Critica,' Mannheim, 1817–29, 4 vols. 4to.; and Orelli's Introduction to his Collection.

INSOLINIC ACID ($C_{18}H_8O_8$) results from the prolonged action of chromic acid upon cuminic acid. It is insoluble in alcohol or ether, and nearly insoluble in water, hence its name. It is bibasic, its salts being formed by the replacement of two atoms of hydrogen by metals; the neutral potash salt contains ($C_{18}H_6K_2O_8$), the acid salt ($C_{18}H_7KO_8$).

Insolinic acid is interesting as being one of the few members of the series of bibasic acids having the general formula $C_nH_{n-10}O_8$. This series is derived from the aromatic acids (benzoic, &c. $C_nH_{n-8}O_4$), and bears a similar relation to those acids that the series $C_nH_{n-2}O_8$ does the formic and acetic series of acids ($C_nH_nO_4$).

INSOLVENCY.—INSOLVENT, a man who cannot pay his debts. [BANKRUPT.] In this country, statutes have from time to time been passed for the purpose of releasing from prison, and sometimes from their debts, persons whose transactions have not been of such a nature as to subject them to the Bankrupt Laws. These statutes have been passed for a limited time only, and have been continued by subsequent enactments.

The Insolvent Law of England was consolidated by the 7 George IV. c. 57, continued and extended by the 1 & 2 Vict. c. 110, and the 2 & 3 Vict. c. 39. The law is administered by commissioners appointed by the crown, in a court called the Insolvent Debtors' Court, and in the country by the judges of the County Courts (10 & 11 Vict. c. 102).

By the 1 & 2 Vict. c. 110, no person shall be arrested upon mesne process in any civil action, except in certain cases specially provided for by the act. [ARREST.]

A person who is in prison charged in execution for any debt or damages, or otherwise committed as mentioned in the act, may, within fourteen days after the commencement of the imprisonment, petition the court for his discharge in the manner prescribed by the act, and he must in such petition state his willingness that all his real and personal estate and effects shall vest in the provisional assignee of insolvent debtors' estates; and if within twenty-one days after the like time he does not make satisfaction to the creditor at whose suit he is so charged or committed, such creditor (or other person mentioned in the act) may petition the court for an order vesting all the real and personal estate of the prisoner in such provisional assignee. When such petition has been filed, and the court has made the order above referred to, all the prisoner's real and personal estate, and everything which he may in any way acquire before his final discharge, is vested in the provisional assignee by virtue of such order when recorded, except the wearing apparel, tools, &c., of the debtor, not exceeding in the whole 20l. in value. The prisoner must also file a schedule of all debts owing by him, and of all his property. The court has power to appoint assignees for the management of the insolvent's estate; and on such assignees assenting to the appointment, all the estate of the insolvent, which was vested in the provisional assignee, becomes immediately vested in such assignees for the payment of the prisoner's debts. After the court shall have adjudged the discharge of the insolvent, he is not liable to imprisonment for any debt in respect of which the adjudication was made. But any property which he may acquire subsequent to his discharge may be taken in execution, under the provisions of the act, for the payment of his unsatisfied debts; and if the property be of such a nature that it cannot be taken in execution, the court may imprison the insolvent till he conveys such property, as the court may direct, for the general benefit of his creditors. It is unnecessary to specify the various provisions of the insolvent laws; their general object is to release the debtor from prison, to free his person from liability as to debts contracted previous to his discharge, but to make all his present and future acquired property available for the benefit of his creditors. Where new creditors have a claim on the insolvent's subsequently acquired property, which is of such a nature that it cannot be taken in execution, it may be necessary to apply to a court of equity, which in administering such estate of a deceased insolvent, will pay the creditors subsequent to the insolvency first, and then the creditors prior to the insolvency.

In cases where it is proved that the insolvent has fraudulently made away with his property, or that his debts were fraudulently contracted, the court does not discharge his person immediately, but has power to order him to be imprisoned for a period not exceeding three years from the date of his petition to the court for his discharge.

There is another statute in the English law (32 George II. c. 28), generally called the Lords' Act, from its having originated in the House of Lords, also continued and extended by subsequent enactments, which enable a debtor taken in execution for a debt not exceeding 300l. to obtain his discharge upon surrendering all his effects (except apparel, bedding, and tools of trade, not exceeding 10l. in the whole) to his creditors.

The above proceedings for relief are applicable only after arrest and imprisonment; and no relief could be obtained by a *cessio bonorum* made before imprisonment by a person not a trader within the meaning of the Bankrupt Acts, until the passing of the 5 & 6 Vict. c. 116, which has since been amended by 7 & 8 Vict. c. 70, and c. 96.

The act 5 & 6 Vict. c. 116, which came into operation 1st November, 1842, enabled a person who was not a trader within the meaning of the Bankrupt Laws, or a trader who owed debts which amounted in the whole to less than 300l., to obtain by petition a protection from the Court of Bankruptcy in London, or the Commissioners of the District Courts of Bankruptcy in the country, from all process whatever (except under a judge's order), either against his person or property, until the case was adjudicated by the court. In the interim, the insolvent's property was vested in an official assignee appointed by the court. If, on the hearing of the petition, the commissioner were satisfied with the allegations which it contained, and that the debts were not contracted by fraud, breach of trust, or by any proceedings for breach of the laws, he was empowered to make a final order for the protection of the petitioner from all process, and to cause his estate and effects to be vested in an official assignee, together with an assignee chosen by the creditors.

The act 7 & 8 Vict. c. 96, passed 9th August, 1844, is entitled "An Act to amend the law of Insolvency, Bankruptcy, and Execution." It enacts, that any prisoner in execution upon judgment in an action for debt, who is not a trader, or whose debts, if a trader, are under 300*l.*, may, without any previous notice, by petition to any court of bankruptcy, be protected from process and from being detained in prison for any debt mentioned in his schedule; and if so detained, the commissioners of any bankruptcy court may order his discharge.

The property of the insolvent may be seized for the benefit of his creditors, with the exception of the wearing apparel, bedding, and other necessaries of the petitioner (the insolvent under 7 & 8 Vict. c. 96) and his family, and the working tools and implements of the petitioner, not exceeding in the whole the value of 20*l.* Under the 7 & 8 Vict. c. 96 (§ 39), if a petitioner for protection from process (pursuant to the provisions of that act) shall wrongfully and fraudulently omit in the schedule—which schedule he is required to make (5 & 6 Vict. c. 116)—any property whatsoever, or retain or exempt out of such schedule any wearing apparel, bedding, or other necessaries, property of greater value than 20*l.*, he shall, upon conviction, be liable to be imprisoned and kept to hard labour for any period not exceeding three years.

The 7 & 8 Vict. c. 96, made a great alteration as to debts under 20*l.* The 57th section is as follows: "Whereas it is expedient to limit the present power of arrest upon final process, be it enacted, that from and after the passing of this act, no person shall be taken or charged in execution upon any judgment obtained in any of her Majesty's superior courts, or in any county court, court of requests, or other inferior court, in any action for the recovery of any debt wherein the sum recovered shall not exceed the sum of 20*l.*, exclusive of the costs recovered by such judgment."

The jurisdiction of the Court of Bankruptcy under these (protection) statutes was transferred to the Court for Relief of Insolvent Debtors in London, and to the County Courts in country cases, by the 10 & 11 Vict. c. 102.

The 7 & 8 Vict. c. 70 (often called the Gentleman's Act) provides for arrangements between persons not traders within the meaning of the Bankrupt Acts, and their creditors, under the control of the Court of Bankruptcy.

The 8 & 9 Vict. c. 127 gives to creditors the means of obtaining payment of sums under 20*l.*, besides the costs of suit, by process of summoning the debtor before the court for examination, "touching the manner and time of his contracting the debt, the means or prospect of payment he then had, the property or means of payment he still hath or may have, the disposal he may have made of any property since contracting such debt *etal.*" The court is empowered to make an order on the debtor "for the payment of his debt by instalment or otherwise;" and if the debtor fails to attend or to make satisfactory answer, or shall appear to have been guilty of fraud in contracting the debt, or to have wilfully contracted it without reasonable prospect of being able to pay it, or to have concealed or made away with his property in order to defeat his creditors, or to have had since the judgment wherewith to pay the debt, the court may commit him for any time not exceeding forty days; but such imprisonment will not operate in satisfaction for the debt. Wearing apparel and bedding of a judgment debtor, and the implements of his trade, amounting in the whole to a sum not exceeding 5*l.* in value, are exempted from seizure. The proceedings upon a judgment summons under the County Court Acts are of analogous description and effect.

The law of debtor and creditor has been a difficulty in all countries. In England an insolvent debtor may, in certain cases, be subjected to the operation of the Bankrupt Laws. If he cannot claim the benefit of the Bankrupt Laws, he is subject to the law that relates to insolvent debtors. The question of arrest and imprisonment for debt has been chiefly discussed with reference to insolvent debtors; that is, the class of debtors whose debts have not been contracted in the operations of trade or commerce, or under such circumstances as to bring them within the Bankrupt Laws.

The present very learned attorney-general (Sir R. Bethel) has introduced in the present (1860) session of parliament a bill to amend the law of bankruptcy; to assimilate the law relating to insolvents who are not traders to that relating to insolvents who are traders; and to abolish (in practice) imprisonment for debt as a means of obtaining its satisfaction. This admirable monument of Sir Richard Bethel's legislative capacity will, it is to be hoped, receive the sanction of parliament; it at once received the earnest approbation of the commercial community.

INSOLVENCY. [Bankrupt Law of Scotland.] We reserved to this place a notice of the remedy called the process of *cessio bonorum;* or surrender of goods by an insolvent debtor to his creditors on oath. This process is mentioned in the earliest records of the Scotch law under the significant name of the *bare-man process.* It was considered in the local courts, and the benefit of it was allowed, as well by way of defence as by way of suit and action, the debtor swearing that he had not in goods or gear beyond five shillings and a plack, and that of all his gains thenceforth he should assign every third penny towards payment of his debt. (Quon. Att., c. 7; stat. Will., c. 17.) But on the erection of the Court of Session, the process was drawn thither, and remained there to the exclusion of the local judicatories. It then also got the name of *cessio bonorum*, and began to be viewed through the medium of the canon and civil laws: the applicant's character was changed; he was no more a *bare man*, or in a condition of mere destitution; he was a *dyvour*, or spendthrift (from the French *devorer*, to squander or consume one's substance); and his state was infamous.

Acting on these principles the Court of Session which up till the Union usurped a legislative power in many matters, in 1606 appointed a pillory near the market-cross of Edinburgh, with a seat upon it, where all dyvours were to be exposed on a market-day at noon, with a bonnet of yellow which was to be worn by them constantly under the pain of three months' imprisonment, if apprehended at any time without the same. This, *the dyvour's habit*, was by the same authority changed in 1665, and appointed to be a coat or upper garment, whereof the one half should be yellow, and the other half brown, with a cap or hood of the same. It was also enacted in 1685, that the insolvent should specially prove how he became bankrupt; and shortly afterwards he was required to produce a certificate that *he had been the space of one month in prison.*

The consequences of such legislation might be anticipated. Continuance in jail was better than delivery on such terms; and accordingly the jails of the kingdom were in course of time filled with miserable objects. To remedy this evil an act was passed in 1696, called the *Act of Grace*, which on the preamble that "generally the burghs of the kingdom are troubled and overcharged with prisoners thrust into their prisons, who have nothing to maintain themselves, but must of necessity either starve or be a burden on the burgh," declared it lawful to the magistrates of burghs to liberate indigent debtors, if, after notice to them to that effect, the creditors failed to provide them aliment at the rate mentioned in the statute. But so entirely was the true source of the evil overlooked that in the same year an act was passed in parliament expressly forbidding the lords of session to dispense with the *bankrupt habit* in any case of *cessio bonorum*, unless the bankrupt's failing "through misfortune" were libelled, sustained, and proved; and so late as 1775, the court refused to dispense with the habit. Sounder and more humane notions began to prevail however, and generally the habit was in later times dispensed with by the court. These notions were unquestionably derived from England; and it is to the House of Lords, in its appellate jurisdiction, and to the British parliament, that the present state of the Scotch insolvent law, its restoration to its ancient condition, is to be traced.

The process of *cessio bonorum* has been modified by modern legislation, the "bankrupt habit" entirely abolished, and a jurisdiction in *cessio* conferred on the Sheriff Courts. The effect of a decree of *cessio* is not to discharge the debtor, but merely to relieve him from the operation of personal diligence or attachment of his person. It affords no protection against the attachment by his former creditors of any property which he may subsequently acquire by personal industry or otherwise, if the goods already surrendered fall short of extinguishing his debts.

INSOLVENT DEBTORS. [Insolvency.]

INSPIRATION. [Revelation.]

INSTINCT, according to Beattie ('Moral Science,' c. ii. sec. 8), is a natural impulse to certain actions which animals perform without deliberation, and without having any end in view, and without knowing why they do it. Lord Brougham, in his 'Dialogue upon Instinct' first published in his edition of Paley's 'Natural Theology,' in 1839, separates instinct into physical and mental. He says "physical instincts are independent of will or mind altogether, though they never are found except where animal life—and consequently mind, exists; but yet mind may influence them. Just so the mental instincts are independent of reason altogether, though they are found in union with it, and reason may influence them."

That the spontaneity of instinct operates unconsciously is fully established by observation. A calf butts with its head before its horns are grown; and the hen broods over the eggs of another species, or even simulated eggs, as patiently as over its own. Lastly, children in certain states of the body are observed to devour eagerly chalk and other earths which are the proper remedies for the disease, although they can have no knowledge of their beneficial nature. Generally indeed this involuntary direction of animal activity appears to be determined by certain organic states which give rise to a vague feeling of desire or aversion, whereby different species of animals are impelled to pursue or to avoid particular objects as necessary for carrying out the purposes of their existence.

In the civilised state of man it is extremely difficult to distinguish the effects of habit from the operations of nature, but from observation of the states of childhood and barbarism the ordinary instincts of the human species are apparently few in number. In children the action of sucking is generally considered instinctive, and, in a barbarous state, the first coming together of the sexes. The latter however has been denied by Hartley, as the former has by Priestley, who considers it to be purely mechanical, like the action of breathing, which Reid has incorrectly classed among instinctive actions. Besides these there are certain extraordinary instincts which are evoked by diseases, in consequence, it would seem, of a change in the mixture of the organical elements of the body. It is thus that the instinctive taste for acid drinks in the feverish patient, and the ravening of children for chalk, &c., which has been already noticed, are to be explained.

But it is in the brute creation that we meet with the most numerous examples of this original quality. The wasp, which does not itself feed upon flesh, and which knows not that a larva is to proceed from the egg which it has deposited in the sand, collects a number of green worms, and having rolled them up in a circular form, fixes them in the hole in such a manner that they cannot escape. The number of the worms so deposited is exactly proportioned to the time necessary for the growth and transformation of the wasp-worm into a fly, when it issues from the hole and is capable of procuring its own food. An instance of what we have termed extraordinary instinct is afforded by the nymphæ of the *phryganiæ*, commonly called the caddis worm, which cover themselves by means of gluten with pieces of wood, straw, small shells, or gravel. It is necessary that they should always be nearly in equilibrium with the water in which they live. To accomplish this, when their covering is too heavy they add a piece of wood; when too light, a bit of gravel.

Mr. Smellie, from whose work on the 'Philosophy of Natural History' our examples have been drawn, distinguishes two classes of instincts: those which, independent of all instruction or experience, instantaneously produce certain actions when particular objects are presented, or under the influence of peculiar feelings; and those which can accommodate themselves to peculiar circumstances and situations. Of the latter he gives as an instance the adaptive instinct of the ostrich, which, in Senegal, neglects her eggs during the day, but sits upon them in the night; whereas at the Cape of Good Hope, where the heat is less, the ostrich, like other birds, sits upon her eggs both day and night. The distinction however seems unnecessary. By the uniformity of instinctive operations nothing more is meant than that the actions of all the individuals of the species are similar when the circumstances are the same. Under different circumstances the same species may act differently, but the correspondence of individual operations will still continue.

While some writers have gone the length of reducing all the faculties of the human mind to certain instinctive principles of action, others have elevated the animal instincts to a level with rational deliberation. Locke and Lord Brougham hold that animals possess some of the faculties of reason. Descartes holds that all their actions are mechanical. Lord Brougham founds his belief on the fact that all animals have perception, and as this implies consciousness, it must lead in some degree, however restricted, to the possession of reason. This is worked out at considerable length in the dialogue mentioned above. Instinct however differs from intellect by the unerring certainty of the means it employs, the uniformity of its results, and the perfection of its works prior to and independent of all instruction or experience; and lastly, by the pursuit of nothing beyond what conduces directly either to the continuation of the individual or the propagation of the kind. But the arts of rational creatures proceed slowly through diversified and oft-repeated experiments, while the means they employ are always various, and seldom the best and most appropriate; and in their works, though falling far short of perfection in many respects, the difficulty is increased by a voluntary combination of the beautiful with the merely useful.

INSTITUT, NATIONAL. The various academies of learning in France having been dispersed during the first storms of the Revolution, a decree of the Republic, dated 3rd Brumaire of the year IV., established a national academy, called the Institut, consisting of three classes, namely, 1, physical and mathematical sciences; 2, moral and political sciences; 3, literature and the fine arts. The object was to promote the progress of learning, to publish memoirs, to make the nation acquainted with the new discoveries, and to correspond with the learned of other countries. Each class consisted of a certain number of members residing at Paris, and a number of associates in different parts of France, with a small number of foreign honorary members. ('Compte rendu et presenté au Corps Législatif le 1er jour complémentaire de l'an IV., par l'Institut National des Sciences et Arts,' 8vo., Paris, an V., (1797). Bonaparte, after he was made first consul, gave a new organisation to the National Institute, by a decree dated St. Cloud, January, 1803, and made it consist of four classes: 1, physical and mathematical sciences, divided into eleven sections, namely, geometry, mechanics, astronomy, geography, and navigation, general physics, chemistry, mineralogy, botany, rural economy and the veterinary art, anatomy and zoology, and lastly, medicine and surgery. This class consisted of 62 resident members, who could appoint 100 correspondents, including foreigners; 2nd class, French language and literature, consisting of 40 members, like the old Académie Française; 3rd class, ancient history and literature, which corresponded to the old Académie des Inscriptions et Belles Lettres. This class consisted of 40 members and 8 foreign associates, besides 60 correspondents, native and foreign; 4th class, fine arts, divided into five sections, namely, painting, sculpture, architecture, engraving, and music. This class consisted of 28 members and 8 foreign associates, and 36 correspondents, native and foreign. The class of moral and political sciences was suppressed: Bonaparte was never partial to those studies (Thibaudeau, 'Histoire du Consulat.') The vacancies in the respective classes were filled up by the members of each class, but the choice was subject to the approbation of the first consul. An annual allowance of 1500 francs was fixed for each resident member, and a salary of 6000 francs to each of the five perpetual secretaries, of whom there were two for the first class, and one for each of the other three. Annual prizes were also awarded. Bonaparte was named member for the section of mechanics. When he became emperor the Institut took the name of Imperial.

After the Restoration, Louis XVIII., by an ordonnance, 21st March, 1816, without changing the arrangement of the departments of each class, restored the old names of Académie de Sciences, Académie Française, Académie des Inscriptions et Belles Lettres, and Académie des Beaux Arts, giving to each a more independent organisation, but still keeping them united in one academical body called the Institut. Louis Philippe, by a royal ordonnance, October 26, 1832, added a fifth class, or 'Academy of Moral and Political Sciences,' divided into five sections, and consisting of 30 resident members and 5 foreign associates, besides about 30 correspondents. ('Almanach Royal et National,' for 1837.) This constitution has been continued under the Emperor Napoleon III. These various classes or academies have published many memoirs and reports; those of the Académie des Inscriptions, styled 'Mémoires de l'Institut par la classe d'Histoire et de Littérature ancienne,' 4 vols. 4to., Paris, 1818, contain many valuable papers. See also the annual 'Compte Rendu,' on the state of science in France, and the 'Discours,' or orations pronounced at the reception of every new member.

INSTITUTION. [Benefice.]

INSTRUMENTS, ASTRONOMICAL, are described under several heads.

For *Meridian* and *Vertical* circles see Circle.

For the *repeating* circle (Borda's and Reichenbach's) see Repeating Circle.

For the *sextant* and other *reflecting* instruments see Sextant. The Transit, Equatorial, Zenith Sector, and Collimator, are described under their respective titles.

For the apparatus used in measuring small quantities and subdivisions, see Micrometer; Vernier.

The machines for *measuring time* are described under Horology; Pendulum.

See also Graduation; Telescope; Observatories.

INSTRUMENTS, MUSICAL, are, 1. *Keyed*, as the organ, pianoforte, &c.; 2. *Stringed*, as the violin, violoncello, &c.; 3. *Wind*, as the flute, horn, &c.; and 4. of *Percussion*, as the drum, cymbals, &c. See the various instruments under their respective names.

INSULATION. [Electricity, Common.]

INSURANCE, FIRE. Associations for securing individuals from the ruinous consequences of accidents beyond their own control now form almost a necessary part of our social institutions. Among such combinations for the security of individuals, companies for assuring the owners of property from loss arising from fire are among those of most obvious utility, and have long been successfully established in this country. It might have been expected that the great advantage to society of individuals providing against their ruin by means of trifling annual contributions would have been felt and acknowledged on the part of the government, so far at least as to prevent the imposing of a tax upon the prudence of the people. Such however is not the fact, and a duty is levied at the rate of 3s. per cent. per annum upon the amount of property insured against destruction by fire, which rate is, in all cases, equal to 200 per cent upon the premium demanded by the insurance offices, and which is found sufficient to cover all losses, as well as to defray the expenses of management, and to afford an adequate return to capitalists who embark their property in the undertaking. This rate is 1*s*. 6*d*. per cent. for all property deemed non-hazardous; for property considered hazardous, higher rates of insurance are taken, and in some cases by special agreement only, or are wholly refused, as in the case of powder-mills. How far the imposition of this tax prevents insurances being effected it is not possible to determine. That many persons neglect to insure against the risk of fire from being compelled to pay 4*s*. 6*d*. for each 100*l*. value of their property, who would not neglect such precaution if they could attain security by payment of 1*s*. 6*d*. for a like amount, will be readily acknowledged; and the propriety of repealing this tax has been frequently urged. But this tax produced to the revenue in 1858 the sum of 1,503,010*l*., and as the amount is raised without trouble and at little cost, the tax offers to the minister of the day an inducement for its continuance which it will be difficult to overcome. There is besides no individual who can complain of special injury or grievance from the tax, and the insurance offices, by which it is collected and paid over to the government, have a special advantage in its continuance, in respect of the discount or allowance which is made to them on the amount. During a period of distress experienced by the agriculturists, the landowners and farmers of the United Kingdom, through their representatives in parliament, recently obtained an advantage over other classes of the community by the repeal of the duty upon insurance of farm produce.

The value of property insured against fire in the United Kingdom may be ascertained from the gross amount of the duty collected; this value in 1858 was 1,001,872,815*l.*; and the value of farm produce insured was 73,570,481*l.*

INSURANCE, LIFE. [REVERSIONS.]

INSURANCE, MARINE, was probably introduced into this country from Italy by the Lombards, together with many other commercial institutions, about the 13th century. The earliest specific record of its existence in legal history is a reference in Lord Coke's 'Reports,' part vi., 47 b, to a case decided in Michaelmas Term, an. 30 & 31 Eliz.; but the antiquity and prevalence of its practice is evidenced by a statute passed shortly afterwards, in the 43rd year of the reign of Elizabeth, whereby, after reciting that such assurances had existed time out of mind, a particular court called the Court of Policies of Assurance (since fallen into disuse) was constituted for the determination in a summary manner of disputes arising out of insurances.

A marine insurance is a contract entered into between persons having some pecuniary interest in ships, their cargo, or their earnings, on the one side; and other persons, who, in consideration of a premium or money payment, varying with the risk, but payable in any event, undertake to indemnify (insure) the former against specified losses at sea. The insurers are ordinarily termed *underwriters*, because they write their names at the foot of the policy opposite that portion of the whole amount to be insured which they severally insure.

Underwriting is a business still carried on principally by individuals; indeed, until 1824, it was, by statute, illegal for any partnership or corporation other than the Royal Exchange Assurance, and the London Assurance Companies, chartered to underwrite a marine policy. In that year the monopoly was abolished, and there are now three other companies that also insure against marine risks. Even prior to 1824 numerous clubs, or associations of shipowners, for mutual assurances were established, but these are now generally limited to small risks and short or coasting voyages.

The largest underwriting business in the world is transacted by the underwriters who assemble at Lloyd's,* a name which has thence acquired an unrivalled celebrity upon every sea. These underwriters constitute a powerful association, and their agents are established in every port. The losses insured against are ordinarily perils of the seas, comprising all the dangers incident to navigation; capture by a public enemy, or by pirates, or thieves; fire; jet-ons, that is, the voluntary throwing overboard of goods or merchandise in time of distress; arrests or embargoes laid on by public authority; and fraudulent conduct (called barratry) of the master or mariners. Against all these risks the underwriters severally engage to indemnify during the particular voyage, or for the period of time specified in the policy; and even if the vessel should in fact be lost at the time when the policy is executed (the circumstance being then unknown to both parties), the insurance is, by the ordinary form of these contracts, binding, it being the practice in our English policies to insure, "lost or not lost," words not usually inserted in the insurances of other nations. But the voyage marked out in the policy must be always exactly pursued; for the slightest deviation from it, except under circumstances of absolute necessity, will render the insurance ineffectual; and that, whether the loss be occasioned by the deviation or not, and whether the ship resume her proper course or not, before the loss happens. Every marine policy for a specific voyage is made under an implied warranty that the ship shall, at the time of the commencement of the risk, be seaworthy, that is, in a condition to perform the voyage; and if the fact turns out to be otherwise, the assured is not entitled to recover in the event of a loss, whether the loss proceed from the defects in her condition or from any other cause.

The assured is entitled to claim upon the policy, not only where he is able to give direct proof of the loss, but where he can show circumstances from which a loss may reasonably be presumed, as that a reasonable time has elapsed for receiving intelligence of the vessel since her departure, and that none has been received; for it will be inferred, under such circumstances, that she has foundered. (Payment by underwriters, under such circumstances, is accepted by the Court of Probate as very strong evidence of the death of those on board.) But where direct proof of the calamity is given, it may turn out that it is either a total, or a partial (called also an average) loss. A total loss, again, may be either actual or constructive; the first, where the thing insured is absolutely destroyed, so as to remain no longer in specie, or so damaged that it cannot ever arrive in specie at the port of destination; the second, where the injury it has sustained, though short of that above supposed, is so great as to make it reasonable that the assured should claim as for a total loss, leaving the underwriter to recover what he can out of the shipwreck or other calamity. And this case seems to arise whenever the nature of the loss is such as to afford reasonable ground to the assured for relinquishing the voyage altogether, as where the ship or goods, as the case may be, are so damaged as not to be worth the expense of repairs or of being forwarded. But in order to claim as for a total loss by construction only, the assured is bound formally to cede or abandon all his remaining right in the property to the underwriter; and unless notice be given him of such abandonment, within a reasonable time after intelligence of the circumstance is received, the loss may be treated as a partial one only. In every case of partial loss, the underwriter is liable to pay such proportion of the sum he has subscribed as the damages sustained by the subject of insurance bears to its whole value at the time of insurance; in the case of a total loss, he is liable to the entire amount of his total subscription, not exceeding the value of the interest in the thing lost of the person claiming under the policy. The underwriter is also, by the effect of a special clause usually introduced into policies, made liable to indemnify the assured in respect of any payment he may have properly made for salvage (that is, for the defence, safeguard, or recovery of the ship or goods), or in respect of general average, which latter subject is of a kind to require special notice. [AVERAGE.]

A stamp duty is levied upon all policies of marine insurance, which is very unfairly made to increase with the risk. (Stephen's 'Comms.,' 4th edit., vol. ii., p. 126 *et seq.* See further Arnould, 'On Marine Insurance.')

INTA'GLIO, an Italian word composed of *in* and *tagliare*, to cut. It is a term of art applied to small works of the gem class, in which the design is indented, or engraved, to distinguish them from those in which the subject or device is raised, called CAMEOS, and under which head will be found a brief notice of the history of both kinds of gem engraving. The French call such sunken works "en creux." Dies from which coins and medals are struck are also engraved in intaglio, but the process is technically known as DIE-SINKING, and has been treated of under that head. The present article will be confined to the depressed or incised engraving of precious stones.

The earliest reference to works in *intaglio* is in the sacred writings, where they are spoken of as being employed for stamps or seals for giving authority to decrees, contracts, and similar purposes. In the Old Testament frequent notices of them occur, as among others, when Tamar desired a pledge from Judah he gave her his signet (Genesis, xxxviii. 18). Another instance is in the description of the sacerdotal breastplate, where we are told the stones that were set in it were to be "like the engravings of a signet, every one with his name." (Exodus, xxxix.); showing by this general reference that such engraving, or working in intaglio, must have been well known at that time.

Among the ancient Greeks and Romans, the art of engraving in intaglio was extensively practised, from the custom of wearing a signet ring being general among freemen. The Greeks carried this branch of the fine arts to the same perfection which their genius and feeling for the beautiful enabled them to reach in all others to which they devoted their attention; but we do not trace its existence among them to a very remote date. It has been supposed that as Homer does not allude to seals they were not used in his time. The earlier engravings for signets probably were mere rude symbols; the exquisite designs produced by Pyrgoteles and others of the more renowned seal engravers of the best period of Greek art were the ultimate results of a prolonged course of experiment, practice, and observation, pursued concurrently with the progress of the arts of design generally. As was said under CAMEO, the art of gem engraving reached its highest point of perfection in the time of Alexander, and it continued to flourish for a long period afterwards. And the Greek engravers also found ample patronage in Rome, where the possession of choice engraved gems both intaglios and cameos, became a passion. The extravagant fondness of the Roman matrons for engraved gems was satirised by Juvenal, and gave rise to the remark of Pliny, that they "loaded their fingers with princely fortunes." This profusion gradually extended itself to the wearing apparel of both sexes; and among the opulent classes almost every article of use or dress glittered with engraved gems. The endless quantities of intaglios and cameos to be found in private collections as well as in the public museums of Europe would alone suffice to prove that there could have been no exaggeration in the statements of contemporaries. Many of these ancient intaglios are of the most exquisite design and execution; pure in taste, refined in drawing, and modelled with almost faultless delicacy and precision. Many of course are of very inferior quality, and it is only due to admit that though essentially imitative in style many of the cinque-cento intaglios are little inferior in execution to the finest of the antique specimens.

The gems employed by the ancient intaglio engravers (scalptores) for engraving on, were chiefly some of the many varieties of the agate, as cornelians, chalcedony, onyx, sardonyx, &c., with jasper and other opaque varieties of quartz; and sometimes even the amethyst, hyacinth, garnet, and other transparent precious stones. They likewise employed artificial gems or pastes, and some of the finest intaglios remaining are of this kind.

There has been much discussion as to the process by which the ancient gem engravers executed works which are now justly referred to as the best examples of the art. It has been a question with antiquaries whether the lathe was known; but though it is not described by any ancient writer, the works themselves seem to afford evidence of its employment, and Pliny refers to the invention of an instrument which he calls "tornum" ('Nat. Hist.' lib. vii.), which may fairly be supposed to mean a turning machine or tool. It is certain they were acquainted with the use of diamond-powder, though Naxian dust appears to have been chiefly used. The stone was first brought to the requisite form and surface by a polisher (politor): when the engraving was executed by the sculptor who employed various kinds of steel instruments, with emery, or Naxian dust, and oil, as a medium, or a diamond point set in steel; and in the finishing, to which the Greeks paid the utmost attention, probably using the diamond-dust instead of emery. (See Muller, 'Arch. der Kunst.,' § 313 &c., and the authorities there cited.)

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* Formerly a coffee-house in Abchurch-lane, Lombard-street, now a subscription-room for the transaction of the business of marine assurance (connected with "Merchants', Captains', and Refreshment Rooms") in the Royal Exchange.

The modern practice of cutting stones in *intaglio* is by an apparatus similar in principle to the turning lathe, which gives the cutting tool, placed horizontally, a quick rotatory motion, and the stone on which the design is to be engraved being brought in contact with it, the surface is ground away or indented, till the effect required is produced. Instruments of various sizes are used, which can easily be removed and replaced, and it is usual, during the process of engraving, to supply the points of the tools with diamond-dust mixed with a little sweet oil. As the work proceeds proofs are occasionally taken in wax.

INTEGER, a whole number, as distinguished from a fraction. The more common name for a multiple of unity is "whole number," meaning a number of units without any broken unit or fraction of a unit. But if the student find any difficulty in separating the word "whole" for this purpose from its common meaning, he may accustom himself to the word integer. We are led to this remark by finding in a work of celebrity an attempt to connect the word "whole," as used in "whole number," with its general meaning, as when we say the whole is greater than its part, as follows: "Integers may be considered as numbers which refer to unity, as a whole to a part."

INTEGRAL CALCULUS. The integral calculus is the inverse of the DIFFERENTIAL CALCULUS; that is to say, if A being given, it be a question of the differential calculus to find B; then B being given, it is a question of the integral calculus to find A.

The question of finding a differential coefficient requires the attainment of the limit of the ratio of two simultaneously diminishing increments of y and x, y being a function of x: and therefore the fundamental question of the integral calculus is as follows: knowing the limit of ratio of the increment of y to the increment of x, required the function of x which y is. Or, having given a function of x, required that function of which the given function is the differential coefficient.

But though this view of the fundamental question is sufficient in pure mathematics, it is not calculated to connect the process of integration with those conceptions which the mind employs in application to geometry or mechanics. We are here accustomed to a rough species of integral calculus, with which the preceding seems at first to have no connection. Thus a number of small straight lines joined together appear to compose a curve with sufficient exactness [ARC]: we arrive at the calculation of a body's variable motion by supposing it uniform during small intervals, and accelerated at the end of each interval [ACCELERATION]; and we obtain the area of a curve with any degree of exactness by subdividing it into a large number of small curvilinear areas, for each of which we substitute a rectangle [AREA]. It should seem then that when, making the proper use of the terms [INFINITE], we say that every magnitude is made up of an infinite number of infinitely small parts, we might add that every one of the parts is of a more simple kind than the whole. Thus we appear to have a right to say that a *curve* is made of infinitely small *straight lines*; that *gradual* variable motion is made up of infinitely small separate *impulses*; that the area of a *curve* is made up of infinitely small *rectangles*. A correct understanding of this connection is the key to that of the integral calculus, and most completely so to that of its ready application.

The student who has read the articles above cited may now endeavour to connect the results, and others of the same kind, by the following generalisation. Let a whole be divided into parts, and let each part be capable of subdivision into two parts, one of which can be simply explained and found, and the other of which would be as difficult to find as the whole itself. Let $\mathrm{A}+a$ be the first part, of which A is of the former species, and a of the latter. Let $\mathrm{B}+b$, $\mathrm{C}+c$, &c., be the other parts, of which B, C, &c., are of the former, and b, c, &c., of the latter species. Then the whole question is

$$\mathrm{A}+\mathrm{B}+\mathrm{C}+\;\ldots\ldots\;+a+b+c+\;\ldots\ldots;$$

by which nothing is gained as yet, for a, b, c, &c., are of as much difficulty as the whole which is to be found. But suppose that when the number of parts is considerable, a is very small compared with A, even though A should be small; and the same of b compared with B, and c compared with C, &c. Then the whole in question is nearly found by adding A, B, C, &c.: for say that a were less than the thousandth part of A, b less than the thousandth part of B, and so on; then $a+b+c+\ldots\ldots$ is also less than the thousandth part of $\mathrm{A}+\mathrm{B}+\mathrm{C}\ldots\ldots$, or the latter may be taken for the whole with an error of less than one in a thousand. Further, suppose that by taking a number of parts sufficiently great, we can make a, b, c, &c., as small as we please in comparison of A, B, C, &c., then $a+b+c+\ldots$ may be as small a part as we please of $\mathrm{A}+\mathrm{B}+\mathrm{C}+$ &c. Consequently, by continuing this process without limit, the limit of the summation of $\mathrm{A}+\mathrm{B}+\mathrm{C}+\ldots$ is the whole required, without the necessity of paying attention to the remaining portions.

Now let ϕx be a function of x, of which the differential coefficient $\phi' x$ does not become infinite when x has any value between a and $a+b$. Then [TAYLOR'S THEOREM] it may be shown that, whenever x and $x+h$ lie between those values,

$$\phi\,(x+h)-\phi x=\phi' x\,.\,h+\mathrm{P}h^2,$$

where P is not such a function of x and h as would hinder Ph and h diminishing without limit together. Let a become $a+b$ by the steps $a+\theta$, $a+2\theta$, ….. $a+n\theta$, $n\theta$ being $=b$. We have then

$$\begin{aligned}
\phi\,(a+\theta)\;-\;\phi a\qquad\quad &= \phi' a\qquad\qquad\;\;\theta+\mathrm{A}\theta^2\\
\phi\,(a+2\theta)-\phi\,(a+\theta) &= \phi'\,(a+\theta)\;\;\theta+\mathrm{B}\theta^2\\
\phi\,(a+3\theta)-\phi\,(a+2\theta) &= \phi'\,(a+2\theta)\;\theta+\mathrm{C}\theta^2\\
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\phi\,(a+n\theta)-\phi\,(a+\overline{n-1}\theta) &= \phi'\,(a+\overline{n-1}\theta)+\mathrm{Z}\theta^2
\end{aligned}$$

A, B, C, … Z, being functions of the same species as P. Sum these, remembering that $n\theta=b$, and we find that

$$\phi\,(a+b)-\phi a$$

is made up of the following series:—

$$\begin{aligned}
&\left\{\phi' a+\phi'\,(a+\theta)+\phi'\,(a+2\theta)+\;\ldots\ldots\;+\phi'\,(a+\overline{n-1}\theta)\right\}\theta\\
&\left\{\mathrm{A}\theta+\quad\;\mathrm{B}\theta\quad+\quad\mathrm{C}\theta\quad+\qquad\qquad+\quad\mathrm{Z}\theta\qquad\qquad\right\}\theta
\end{aligned}$$

If then we diminish θ without limit, or increase without limit the number of steps by which we pass from a to $a+b$, we have before us such a case as has been already described. Let p be the least value of $\phi' x$ corresponding to values of x between a and $a+b$: then the ratio of any term in the first series to the corresponding term in the second cannot fall short of that of $p\theta$ to $\mathrm{A}\theta^2$, or $\mathrm{B}\theta^2$, &c., or the ratio of p to $\mathrm{A}\theta$ or $\mathrm{B}\theta$, &c. But by diminishing θ without limit, all the preceding ratios are increased without limit; that is, the ratio of the first series to the second series is increased without limit. We have then the following equation:—

$\phi\,(a+b)-\phi a=$ limit of $\Sigma\,(\phi' x\,.\,\Delta x)$ beginning at $x=a$ and ending when $x=a+b$: or, if the interval from a to $a+b$ be divided into n parts, each of the value Δx (called θ in the preceding), and if x be made successively equal to a, $a+\Delta x$, …. $a+b-\Delta x$, then the sum of all the values of $\phi' x$, each multiplied by Δx, approaches without limit to $\phi\,(a+b)-\phi a$, when n is increased, or Δx diminished without limit. Now the same sort of convention by which [DIFFERENTIAL CALCULUS] the limit of $\dfrac{\Delta y}{\Delta x}$ is expressed by $\dfrac{dy}{dx}$ is here extended, and the limit of $\Sigma\,(\phi' x\,.\,\Delta x)$ is written $\int\phi' x\,.\,dx$. The beginning and final values of x are placed above and below the integral sign $\int$: thus the preceding equation is written

$$\phi\,(a+b)-\phi a=\int_a^{a+b}\phi' x\,dx.$$

It is common to represent the terminal value of x by x itself, as follows:—

$$\phi x-\phi a=\int_a^x\phi' x\,dx,$$

and when the initial value of x is left indefinite, then a simple constant is written for ϕa, and the symbols of the limits are omitted, as follows:—

$$\phi x=\int\phi x\,dx+\mathrm{C}.$$

Let us now suppose a given function fx, upon which we wish to perform the preceding summation, from $x=a$ to $x=a+b$; namely, making $n\,\Delta x=b$, we desire to find the limit of

$$\left\{fa+f\,(a+\Delta x)+\;\ldots\ldots\;+f\,(a+b-\Delta x)\right\}\Delta x$$

on the supposition that n is increased, or Δx diminished, without limit. This process can be performed immediately, if we can find the function which has fx for its differential coefficient. Let $f_1 x$ have the diff. co. fx; then, by the preceding theorem, the required limit of the summation is

$$f_1\,(a+b)-f_1 a.$$

For instance, so soon as we know that $\dfrac{1}{x}$ is the differential coefficient of log x, we know that log $(a+b)-$ log a is the limit of the following series,

$$\frac{\Delta x}{a}+\frac{\Delta x}{a+\Delta x}+\frac{\Delta x}{a+2\Delta x}+\;\ldots\ldots\;\frac{\Delta x}{a+b-\Delta x}$$

the number of terms being n, Δx being the nth part of b, and n being increased without limit.

The process in the article AREA will now easily show that, y being the ordinate of a curve to the abscissa x, the area contained between the ordinates whose abscissæ are a and $a+b$, the part of the abscissa b, and the curve, is $\int y dx$ taken from $x=a$ to $x=a+b$. Thus if the curve be a part of a rectangular hyperbola, whose equation is $xy=c$, or $y=\frac{c}{x}$, the area included between the ordinates, whose abscissæ are 1 and $1+k$, is $\int \frac{c}{x} dx$ from $x=1$ to $x=1+k$. But $c \log x$ is the function whose differential coefficient is $\frac{c}{x}$; whence it follows that the preceding area is $c \log(1+k) - c \log 1$ or $c \log(1+k)$ square units. This is the property of the hyperbola from which the logarithms of Napier were called *hyperbolic*. [LOGARITHMS.]

An integral is said to be definite, when its limits are given; and indefinite when they are not given.

INTEGRALS, DEFINITE. [INTEGRATION, DEFINITE.]

INTEGRATION. In the article INTEGRAL CALCULUS, the meaning of an integral was explained. The present article is devoted to the operation of integration, that is, of finding the primitive function which has a given function for its differential coefficient. Having given P a function of x required Q so that $d\text{Q} : dx$ may be P. In the article QUADRATURES, METHOD OF, is given the mode to which we must have recourse, in order to find particular values of Q, when the general methods for determining it fail. In this article we confine ourselves to what is most useful in operation, as a summary for the advanced student, not an explanation for the learner. Properly speaking, the problem requires some addition to make it definite. Thus $2x$ has x^2 for a primitive function, and also $x^2+\text{C}$, C being any constant quantity whatever. In the present article, we shall neglect this constant altogether, reminding the reader that he must never omit it in any application. If he should find in different books different functions given as the primitives of one and the same function, he will always find that those different primitives differ only by a constant quantity. Thus $(1-x)^{-1}$ and $x(1-x)^{-1}$ both occur as the primitive of $(1-x)^{-2}$; but they only differ by a constant, namely 1.

In the common process of integration, the actual passage from the differential coefficient to the primitive is always an act of memory. The algebraical work which occurs is always used either to reduce a form in which memory will not serve into one in which it will, or else to reduce the given differential coefficient to two terms, one of which can be integrated by memory, and the other of which is more simple than the original quantity.

The functions in which the simple remembrance of the forms of the differential calculus is of use are as follows:—

$$\int dx = x, \int a dx = ax, \int x^n dx = \frac{x^{n+1}}{n+1}, \int \frac{dx}{\sqrt{x}} = 2\sqrt{x},$$

$$\int \frac{dx}{x^n} = -\frac{1}{(n-1)x^{n-1}}, \int \frac{dx}{x} = \log x, \int a^x dx = \frac{a^x}{\log a}$$

$$\int \epsilon^{ax} dx = \frac{\epsilon^{ax}}{a}$$

$$\int \sin x\, dx = -\cos x, \int \cos x\, dx = \sin x, \int \frac{dx}{\cos^2 x} = \tan x$$

$$\int \frac{dx}{\sqrt{(1-x^2)}} = \sin^{-1} x, \int \frac{-dx}{\sqrt{(1-x^2)}} = \cos^{-1} x,$$

$$\int \frac{dx}{1+x^2} = \tan^{-1} x$$

To these should be added the following, which may be obtained in various ways from the methods of this article, or from peculiar artifices which are found in works on the subject.

$$\int \frac{dx}{\sqrt{(a^2-x^2)}} = \sin^{-1}\frac{x}{a}, \int \frac{-dx}{\sqrt{(a^2-x^2)}} = \cos^{-1}\frac{x}{a}$$

$$\int \frac{dx}{\sqrt{(x^2 \pm a^2)}} = \log\left\{x \pm \sqrt{(x^2-a^2)}\right\}$$

$$\int \frac{dx}{a^2-x^2} = \frac{1}{2a}\log\left(\frac{a+x}{a-x}\right) \int \frac{dx}{x^2-a^2} = \frac{1}{2a}\log\left(\frac{x-a}{x+a}\right)$$

$$\int \frac{dx}{x^2+a^2} = \frac{1}{a}\tan^{-1}\frac{x}{a} \int \frac{dx}{(a^2 \pm x^2)^{\frac{3}{2}}} = \frac{1}{a^2}\frac{x}{\sqrt{(a^2 \pm x^2)}}$$

$$\int \frac{dx}{\sin x} = \log \tan \frac{x}{2} \int \frac{dx}{\cos x} = \log \cot\left(\frac{\pi}{4} - \frac{x}{2}\right)$$

$$\int \tan x\, dx = -\log \cos x \int \cot x\, dx = \log \sin x.$$

Among the peculiar artifices of integration may be reckoned the following, which are perhaps nearly all that can be useful to a learner:—

1. The reduction of such a form as $\int \text{X} dx$ to another form $\int \text{V} dv$, in which v is a different variable. Thus $\int (a^2+x^2)^n x dx$ can be immediately reduced to $\frac{1}{2}\int (a^2+x^2)^n d.(a^2+x^2)$ or $\frac{1}{2}\int v^n dv$, where v means a^2+x^2. The second form is immediately seen to be integrable. Cases of this kind are so various that the student must form the habit of looking for them, and recognising them at sight. Sometimes a slight transformation is required, thus: $(1+a\epsilon^x)^{-1} dx$, when reduced to $(\epsilon^{-x}+a)^{-1}\epsilon^{-x}dx$ clearly shows the form $-v^{-1}dv$, where v is $\epsilon^{-x}+a$.

2. The reduction of algebraical to trigonometrical functions, and the converse. Thus $(a^2-x^2)^m x^n dx$, if x be made $a \sin\theta$, becomes $a^{2m+n+1}\cos^{m+1}\theta \sin^n\theta d\theta$. Also $\int (\sin\theta, \cos\theta) . d\theta$, if $x=\sin\theta$, becomes $\int \left\{x, \sqrt{(1-x^2)}\right\}.(1-x^2)^{-\frac{1}{2}}dx$.

3. When rational powers appear in a denominator, they should be transferred to the numerator by changing x into $1:z$. By such a transformation, we change

$$\frac{dx}{x^m\sqrt{(a+bx+cx^2)}} \text{ into } -\frac{z^{m-1}dz}{\sqrt{(az^2+bz+c)}}.$$

4. When an irrational root of a polynomial appears in the numerator, it should generally be transferred to the denominator: thus, $\sqrt{\text{X}}\, dx$ should be written $\text{X}dx : \sqrt{\text{X}}$. By such a transformation, we change

$$\sqrt{(a^2+x^2)}\,.\,dx \text{ into } \frac{a^2dx}{\sqrt{(a^2+x^2)}} + \frac{x^2dx}{\sqrt{(a^2+x^2)}}.$$

5. When, by the addition of more simple terms to the numerator, it can be made the differential of the prominent function of the denominator, such additions, with compensating subtractions, will frequently reduce the question of integration to a more simple one. Thus we alter

$$\frac{xdx}{\sqrt{(a+bx+cx^2)}} \text{ into } \frac{1}{2c}\frac{2cx+b-b}{\sqrt{(a+bx+cx^2)}}$$

$$\text{or } \frac{1}{2c}\frac{d(a+bx+x^2)}{\sqrt{(a+bx+cx^2)}} - \frac{b}{2c}\frac{dx}{\sqrt{(a+bx+cx^2)}}$$

the first term of which can be integrated as in (1), leaving the second term, which can be simply integrated.

6. The process known by the name of *integration by parts*, consists in reducing the form $\text{X}dx$ into any convenient form $\text{V}dv$, and using the obvious theorem

$$\int \text{V}dv = \text{V}v - \int v d\text{V},$$

thus the finding of $\int \text{V}dv$ is reduced to that of $\int v d\text{V}$, which it may often happen is the more simple of the two. Thus to find $\int x^m \log x dx$, we have

$$\int \log x d\frac{x^{m+1}}{m+1} = \frac{\log x \,.\, x^{m+1}}{m+1} - \int \frac{x^{m+1}}{m+1}\frac{dx}{x}$$

about the second term of which there is no difficulty. But it often happens that this method succeeds by a succession of reductions. Thus it gives

$$\int \epsilon^x x^6 dx = x^6\epsilon^x - 6\int \epsilon^x x^5 dx$$

in which the second term must be again treated in the same manner; and so on, until we arrive at $\int \epsilon^x dx$.

7. In the last mode of proceeding, it is best to form, in general terms, an *equation of reduction*, as it may be called, which furnishes the key to the reduction of each case to the one below it. Thus if $\int \epsilon^{ax}x^n dx$ be considered as a function of n, and called V_n, integration by parts gives

$$\text{V}_n = a^{-1}\epsilon^{ax}x^n - na^{-1}\text{V}_{n-1},$$

thus showing how to find $\int \epsilon^{ax}x^n dx$ as soon as $\int \epsilon^{ax}x^{n-1}dx$ is known.

8. The use of the equation of reduction depends upon our being able at last to reduce the question to that of finding a visibly known integral. Thus, if in the preceding n be an integer, we must at last come to $\int \epsilon^{ax}x^0 dx$, or $\int \epsilon^{ax}dx$, which is known. But if n were a fraction, no reduction of the value of n by units at a time would lead to an integrable form.

9. The integrable form at which we arrive by successive reductions is called the *ultimate form*. It frequently happens however that the reductions proceed by two or more steps at a time, in which case two or more ultimate forms result. For instance $\text{V}_n = \int (a^2-x^2)^{-\frac{1}{2}} x^n dx$ has for its equation of reduction

$$\text{V}_n = -\frac{x^{n-1}\sqrt{(a^2-x^2)}}{n} + \frac{n-1}{n}a^2\text{V}_{n-2}$$

Accordingly, when n is even, we are brought at last to V_0, and when n is odd, to V_1, or to $\sin^{-1}(x:a)$ and $-\sqrt{(a^2-x^2)}$.

10. In using equations of reduction, it will be found more convenient to work upwards from the ultimate form to the case required, than in the contrary way. Thus if we want $\text{V}_4 = \int \epsilon^x x^4 dx$, the equation of reduction being

$$\text{V}_n = x^n\epsilon^x - n\text{V}_{n-1},$$

we should proceed as follows:—

$$\text{V}_0 = \epsilon^x, \ \text{V}_1 = x\epsilon^x - \epsilon^x$$

$$\text{V}_2 = x^2\epsilon^x - 2(x\epsilon^x - \epsilon^x) = x^2\epsilon^x - 2x\epsilon^x + 2\epsilon^x$$

$$\text{V}_3 = x^3\epsilon^x - 3x^2\epsilon^x + 6x\epsilon^x - 6\epsilon^x$$

$$\text{V}_4 = x^4\epsilon^x - 4x^3\epsilon^x + 12x^2\epsilon^x - 24x\epsilon^x + 24\epsilon^x.$$

11. There are several cases in which the following extension of the theorem known by the name of John Bernoulli may be useful. Let u', u'', &c. be the successive differential coefficients of u with respect to x, and let v_1, v_2, v_3, &c. be the successive integrals of v with respect to x: then

$$\int u\,dv = uv - u'v_1 + u''v_2 - u'''v_3 + \ldots \pm u^{(n)}v_n \mp \int u^{(n+1)}v_n\,dv.$$

This is particularly useful when u is a rational and integral function, and v is successively integrable with ease, as when u is e^{ax}, $\sin ax$, or $\cos ax$. The process can then be continued until the remainder vanishes.

12. In the case of $\phi x dx : \psi x$, where ϕx and ψx are rational and integral functions, the integration is always possible so soon as all the roots of $\psi x = 0$ are found. The process in FRACTIONS, DECOMPOSITION OF, must be applied. When this is done, and the function thereby reduced to the sum of terms of the form $A(x-a)^{-n}dx$, the integration gives no trouble.

13. In the case of a pair of irrational roots, $a \pm \beta\sqrt{-1}$, each occurring once, the sum of the terms which they produce can be reduced to the form

$$\int(Ax+B)dx : \left\{(x-a)^2+\beta^2\right\}$$

the integral of which is

$$\frac{A}{2}\log\left\{(x-a)^2+\beta^2\right\} + \frac{B+Aa}{\beta}\tan^{-1}\frac{x-a}{\beta}.$$

14. When $\phi x dx$ is a function of powers of any one case of $ax+b$, it can, if irrational, be reduced to a rational function by assuming $ax+b=v^m$, where m is the least common multiple of all the denominators in the exponents. For dx becomes $mv^{m-1}dv : a$, and every power of $ax+b$ becomes an integer power of v.

15. The function $x^m(ax+b)^n dx$ can be integrated when either m or n is a positive integer: when n is integer, by simple expansion; when m is integer, but not n, by making $ax+b=v$, and substituting. But when both m and n are negative integers, let $x=1:y$ and after substitution, make $a+by=w$, and substitute for y.

16. The function $\phi x dx : (x^n \pm a^n)$ can be easily integrated by decomposition of fractions, the denominator never having equal roots. The same may be said if we substitute $x^{2n} \pm 2ba^n x^n + a^n$ in the denominator.

17. In $x^r(a+bx^s)^t dx$ we have an integrable function, whenever either of the following is a positive integer:—

$$\frac{r+1}{s},\text{ or } -\frac{r+1}{s}-t$$

The substitutions which succeed in the two cases are

$$a+bx^s = v^\delta,\text{ and } ax^{-s}+b=v^\delta$$

δ being the denominator of t.

18. The following transformation involves a large number of obvious cases, and is constantly occurring. If $\int\phi x dx=\psi x$, then $\int\phi(ax+b)dx=\psi(ax+b):a$.

Thus in no list would $\int\cos(ax+b)dx$ be set down, after $\int\cos x\,dx$ has been given.

19. The following integrals are worth giving separately as ultimate forms:—

$$\int\frac{dx}{x\sqrt{(x^2-a^2)}} = \frac{1}{a}\cos^{-1}\frac{a}{x},$$

$$\int\frac{dx}{x\sqrt{(a^2\pm x^2)}} = \frac{1}{a}\log\frac{x}{a+\sqrt{(a^2\pm x^2)}}$$

$$\int\frac{dx}{\sqrt{(2ax-x^2)}} = \cos^{-1}\frac{a-x}{a} = \text{vers}^{-1}\frac{x}{a}$$

$$\int\frac{dx}{\sqrt{(2ax+x^2)}} = \log\left\{x+a+\sqrt{(2ax+x^2)}\right\}$$

$$\int\frac{dx}{a+bx+cx^2} = 2\int\frac{d(2cx+b)}{(2cx+b)^2+4ac-b^2}$$

which comes under one or another of three previously given forms according as b^2-4ac is positive, nothing, or negative.

$$\int\frac{xdx}{a+bx+cx^2} = \frac{1}{2c}\log(a+bx+cx^2) - \frac{b}{2c}\int\frac{dx}{a+bx+cx^2}$$

$$\int\frac{dx}{\sqrt{(a+bx+cx^2)}} = \frac{1}{\sqrt{c}}\log\left\{2cx+b+\sqrt{\left\{4c(a+bx+cx^2)\right\}}\right\}$$

$$\int\frac{dx}{\sqrt{(a+bx-cx^2)}} = \frac{1}{\sqrt{c}}\sin^{-1}\frac{2cx-b}{\sqrt{(4ac+b^2)}}$$

$$\int\sqrt{a^2+x^2}\,dx = \frac{1}{2}x\sqrt{a^2+x^2} + \frac{a^2}{2}\log\left(x+\sqrt{a^2+x^2}\right)$$

$$\int\sqrt{a^2-x^2}\,dx = \frac{1}{2}x\sqrt{a^2-x^2} + \frac{a^2}{2}\sin^{-1}\frac{x}{a}.$$

Let $X=(a+bx+cx^2)$. Then

$$\int\sqrt{X}.dx = \frac{2cx+b}{4c}.\sqrt{X} + \frac{4ac-b}{8c}\int\frac{dx}{\sqrt{X}}$$

$$\int\sqrt{X}.xdx = \frac{1}{3c}X^{\frac{3}{2}} - \frac{b}{2c}\int\sqrt{X}.dx$$

$$\int\frac{xdx}{\sqrt{X}} = \frac{\sqrt{X}}{c} - \frac{b}{2c}\int\frac{dx}{\sqrt{X}}$$

$$\int\frac{dx}{x\sqrt{X}} = \frac{1}{\sqrt{a}}\log\frac{2a+bx-2\sqrt{(aX)}}{x}$$

$$= \frac{1}{\sqrt{-a}}\sin^{-1}\frac{bx+2a}{x\sqrt{(b^2-4ac)}}$$

$$\int X^{-\frac{3}{2}}dx = \frac{2(2cx+b)}{4ac-b^2}X^{-\frac{1}{2}}$$

$$\text{Let}\int\frac{dx}{a+b\cos x} = \frac{1}{\sqrt{(a^2-b^2)}}\cos^{-1}\frac{b+a\cos x}{a+b\cos x}$$

$$= \frac{1}{\sqrt{(b^2-a^2)}}\log\left\{\frac{b+a\cos x+\sqrt{(b^2-a^2)}.\sin x}{a+b\cos x}\right\}.$$

20. All that it remains to give are the equations of reduction for remarkable cases. Many other differentials can be integrated in a finite form: but it is impossible to give a list of all which are sometimes useful. The transformation of unknown to known forms is one of the most necessary studies of the young mathematician.

21. Let $V_{m,n}=\int(\log x)^m x^n dx$. Then

$$V_{m,n}=(\log x)^m\frac{x^{n+1}}{n+1} - \frac{m}{n+1}V_{m-1,n}$$

22. Let P stand for $Ax^a + Bx^b$, (m, n) for $\int x^m P^n dx$, g and h for $m+1+na$ and $m+1+nb$, and c for $a-b$. We shall then have

$$h(m,n)+ncA(m+a,n-1)=x^{m+1}P^n$$
$$g(m,n)-ncB(m+b,n-1)=x^{m+1}P^n$$
$$gA(m,n)+(h-c)B(m-c,n)=x^{m-a+1}P^{n+1}$$
$$hB(m,n)+(g+c)A(m+c,n)=x^{m-b+1}P^{n+1}$$

from the first pair of which formulæ of reduction can be found for n, be it positive or negative, and for m from the second pair. The most useful cases are those in which $a=0$, $b=1$, and in which $a=0$, $b=2$.

23. Let $V_n=\int(x^2\pm a^2)^{-n}dx$. Then

$$V_n = \pm\frac{x(x^2\pm a^2)^{-(n-1)}}{(2n-2)a^2} \pm \frac{2n-3}{(2n-2)a^2}V_{n-1}.$$

24. Let $V_n=\int(x^2\pm a^2)^n dx$. Then

$$V_n = \frac{x(x^2\pm a^2)^n}{2n+1} \pm \frac{2na^2}{2n+1}V^{n-1}.$$

25. Let $V_n=\int(a^2-x^2)^{-n}dx$ or $\int(a^2-x^2)^n dx$. The equations of reduction are those in (23) (using the + in $\pm$) and in (24), and writing a^2-x^2 for $x^2\pm a^2$.

26. Let $V_{m,n}=\int x^m(a^2\pm x^2)^{-n}dx$. Then

$$V_{m,n} = \mp\frac{x^{m-1}}{2(n-1)}\frac{1}{(a^2\pm x^2)^{n-1}} \pm \frac{m-1}{2(n-1)}V_{m-2,n-1}$$

$$V_{m,n} = \frac{x^{m+1}}{2(n-1)a^2}\frac{1}{(a^2\pm x^2)^{n-1}} - \frac{m+3-2n}{2(n-1)a^2}V_{m,n-1}$$

$$V_{m,n} = \pm\frac{x^{m-1}}{m+1-2n}\frac{1}{(a^2\pm x^2)^{n-1}} \mp \frac{m-1}{m+1-2n}a^2V_{m-2,n}.$$

27. Let $V_m=\int x^m(a^2\pm x^2)^{-\frac{1}{2}}$. Then

$$V_m = \pm\frac{x^{m-1}(a^2\pm x^2)^{\frac{1}{2}}}{m} \mp \frac{m-1}{m}a^2V_{m-2}.$$

28. Instead of giving a large number of forms which are all derivable from (22), it will be better to give an instance of the derivation in full. Let the case be $\int x^{-m}(2ax-x^2)^n dx$, and let the formula be required to reduce both m and n in numerical magnitude. Here, to transform the formulæ in (22),

For m write $-m$; retain n.
For A write $2a$; for B, -1.
For a write 1; for b, 2.
For g, $-m+1+n$; for h, $-m+1+2n$.
For c write -1.

The first formula connects $(-m, n)$ and $(-\overline{m-1}, n-1)$, the second $(-m, n)$ and $(-m-2, n-1)$; the third $(-m, n)$ and $(-\overline{m-1}, n)$; the fourth $(-m, n)$ and $(-m+1, n)$. By either of the first two we can therefore reduce both; by either of the last two we can reduce m only. Observe that whenever a formula will serve to raise either exponent it will also serve to reduce it. Thus, if a formula were

$$V_m=\phi(m,x)+\psi m.V_{m+1}$$

write $m-1$ for m and we have, by transformation,

$$\mathrm{v}_m = -\frac{\phi(m-1,\,x)}{\psi(m-1)} + \frac{1}{\psi(m-1)}\,\mathrm{v}_{m-1}$$

The two first formulæ become (P being $2ax-x^2$)

$$(2n-m+1)\,(-m,\,n) - 2an\,(-\overline{m-1},\,n-1) = x^{-m+1}\,\mathrm{P}^n$$
$$(n-m+1)\,(-m,\,n) - n\,(-\overline{m-2},\,n-1) = x^{-m+1}\,\mathrm{P}^n$$

from which, writing $\mathrm{v}_{m,\,n}$ for $(-m,\,n)$ or $\int x^{-m}\mathrm{P}^n dx$, we have

$$\mathrm{v}_{m,\,n} = \frac{1}{2n-m+1}\,\frac{(2ax-x^2)^n}{x^{m-1}} + \frac{2na}{2n-m+1}\,\mathrm{v}_{m-1,\,n-1}$$
$$\mathrm{v}_{m,\,n} = \frac{1}{n-m+1}\,\frac{(2ax-x^2)^n}{x^{m-1}} + \frac{n}{n-m+1}\,\mathrm{v}_{m-2,\,n-1}.$$

If it were required to reduce n in the preceding without altering m, throw the formula $x^{-m}(2ax-x^2)^n$, into the form $x^{n-m}(2a-x)^n$ and use the first of the four formulæ.

29. All the preceding forms involving $x^m\mathrm{P}^n$ are particularly in use when n is a fraction, positive or negative, with the denominator 2. These in fact form the most usual cases. Formulæ involving the powers of $\mathrm{A}+\mathrm{B}x+\mathrm{C}x^2$ are so little wanted, that they are better omitted in a work in which space is of importance.

30. Let s and c stand for sin θ and cos θ. The integral $\int \mathrm{s}^m\mathrm{c}^n d\theta$, m and n being positive integers, can be immediately found if $\mathrm{s}^m\mathrm{c}^n$ be reduced to the sum of terms of the form $\mathrm{A}\cos k\theta$ or $\mathrm{A}\sin k\theta$. But this process is laborious, except when a simple rule is mastered which seldom appears in works on trigonometry, and is seldom used except when there is some particular reason for exhibiting the result in the form of simple sines and cosines.

31. The following equations of reduction are those which are most commonly used:—

$$\int \mathrm{s}^m d\theta = -\frac{\mathrm{c}\mathrm{s}^{m-1}}{m} + \frac{m-1}{m}\int \mathrm{s}^{m-2} d\theta$$
$$\int \mathrm{c}^n d\theta = \frac{\mathrm{s}\mathrm{c}^{n-1}}{n} + \frac{n-1}{n}\int \mathrm{c}^{n-2} d\theta$$
$$\int \frac{d\theta}{\mathrm{s}^m} = -\frac{\mathrm{c}}{(m-1)\mathrm{s}^{m-1}} + \frac{m-2}{m-1}\int \frac{d\theta}{\mathrm{s}^{m-2}}$$
$$\int \frac{d\theta}{\mathrm{c}^n} = \frac{\mathrm{s}}{(n-1)\mathrm{c}^{n-1}} + \frac{n-2}{n-1}\int \frac{d\theta}{\mathrm{c}^{n-2}}$$
$$\int \mathrm{s}^m\mathrm{c}^n d\theta = \frac{\mathrm{s}^{m+1}\mathrm{c}^{n-1}}{m+n} + \frac{n-1}{m+n}\int \mathrm{s}^m\mathrm{c}^{n-2} d\theta$$
$$= -\frac{\mathrm{s}^{m-1}\mathrm{c}^{n+1}}{m+n} + \frac{m-1}{m+n}\int \mathrm{s}^{m-2}\mathrm{c}^n d\theta$$
$$\int \frac{\mathrm{c}^n d\theta}{\mathrm{s}^m} = -\frac{\mathrm{c}^{n-1}}{(m-1)\mathrm{s}^{m-1}} - \frac{n-1}{m-1}\int \frac{\mathrm{c}^{n-2} d\theta}{\mathrm{s}^{m-2}}$$
$$\int \frac{\mathrm{s}^m d\theta}{\mathrm{c}^n} = \frac{\mathrm{s}^{m-1}}{(n-1)\mathrm{c}^{n-1}} - \frac{m-1}{n-1}\int \frac{\mathrm{s}^{m-2} d\theta}{\mathrm{c}^{n-2}}$$
$$\int \frac{d\theta}{\mathrm{s}^m\mathrm{c}^n} = -\frac{1}{(n-1)\mathrm{s}^{m-1}\mathrm{c}^{n-1}} + \frac{m+n-2}{n-1}\int \frac{d\theta}{\mathrm{s}^m\mathrm{c}^{n-2}}$$
$$= \frac{1}{(m-1)\mathrm{s}^{m-1}\mathrm{c}^{n-1}} + \frac{m+n-2}{m-1}\int \frac{d\theta}{\mathrm{s}^{m-2}\mathrm{c}^n}$$
$$\int \frac{\mathrm{c}^n d\theta}{\mathrm{s}^m} = \frac{\mathrm{c}^{n-1}}{(n-m)\mathrm{s}^{m-1}} + \frac{n-1}{n-m}\int \frac{\mathrm{c}^{n-2} d\theta}{\mathrm{s}^m}$$
$$= -\frac{\mathrm{c}^{n+1}}{(m-1)\mathrm{s}^{m-1}} - \frac{n-m+2}{m-1}\int \frac{\mathrm{c}^n d\theta}{\mathrm{s}^{m-2}}$$
$$\int \frac{\mathrm{s}^m d\theta}{\mathrm{c}^n} = -\frac{\mathrm{s}^{m-1}}{(m-n)\mathrm{c}^{n-1}} + \frac{m-1}{m-n}\int \frac{\mathrm{s}^{m-2} d\theta}{\mathrm{c}^n}$$
$$= \frac{\mathrm{s}^{m+1}}{(n-1)\mathrm{c}^{n-1}} - \frac{m-n+2}{n-1}\int \frac{\mathrm{s}^m d\theta}{\mathrm{c}^{n-2}}$$
$$\int \tan^n\theta\, d\theta = \frac{\tan^{n-1}\theta}{n-1} - \int \tan^{n-2}\theta\, d\theta.$$

32. We have given the last steps in various forms, because in fact all the integrals of the form $\int x^m(a^2-x^2)^n dx$ depend upon them. For if $x = a\sin\theta$, the last integral becomes $a^{m+2n+1}\int \sin^m\theta\cos^{2n+1}\theta d\theta$.

We have now given most of the forms which will be useful in an ordinary work of reference. Further forms and examples will be found in many works on the integral calculus, but the largest collection is in Meier Hirsch's 'Integraltafeln,' Berlin, 1810, 4to, a work of which there is also an English edition.

We have omitted notice of a great many such forms as $\int x^n\epsilon^{ax}dx$, $\int x^n\epsilon^{ax}\cos nx dx$, &c., which are little used, except in particular cases. When $\phi x \,.\, \epsilon^{ax}dx$ can be integrated, it follows that $\phi x \,.\, \epsilon^{ax}\cos bx dx$, &c., can also be integrated, since the second can be made into the sum or difference of two functions of the first form, by putting for cos bx or sin bx their exponential values.

The question of the possibility of integration in finite terms can often be settled by the following theorem:—Integration and differentiation, with respect to different variables, are convertible operations; thus

$$\frac{d\int u dx}{dy} = \int \frac{du}{dy}\,dx.$$

If therefore $\int u dx$ can be found, so also can $\int (du : dy)dx$, if y be not a function of x. From this it will be seen that whenever $\phi x\epsilon^{ax}dx$ can be integrated so can $\phi x\epsilon^{ax}x^n dx$, which is obtained by n differentiations with respect to a; and also that whenever $\phi x \,.\, x^n dx$ can be integrated, so can $\phi x x^n (\log x)^m dx$, which is obtained by m differentiations with respect to n.

Functions involving the transcendental forms $\sin^{-1}\phi x$, &c., can sometimes be reduced to more algebraical forms by integration by parts. Thus,

$$\int \mathrm{v}\sin^{-1}\mathrm{x} \,.\, dx = \sin^{-1}\mathrm{x} \,.\int \mathrm{v}dx - \int \frac{\mathrm{x}'\int \mathrm{v}dx}{\sqrt{(1-\mathrm{x}^2)}}\,dx$$
$$\int \mathrm{v}\log \mathrm{x}dx = \log \mathrm{x} \,.\int \mathrm{v}dx - \int \frac{\mathrm{x}'\int \mathrm{v}dx}{\mathrm{x}}\,dx, \text{ \&c.}$$

in which x' means $d\mathrm{x} : dx$.

INTEGRATION DEFINITE. In the preceding article we have given some idea of the usual modes of integration. The results, which in the present article are given under the name of *definite integrals*, are mostly cases in which it is possible to find an integral when both limits are given [INTEGRAL CALCULUS]; but not possible to find the integral in all cases. If we can integrate $\phi x dx$ generally, that is, if we can find the function $\phi_1 x$, of which ϕx is the differential coefficient, we can always express the integral, the limit of the summation in the article just referred to, as follows:—

$$\int_a^b \phi x dx = \phi_1 b - \phi_1 a$$

but it frequently happens that ϕx is a function for which this cannot be done in a finite form, except for certain values of a and b. And it happens almost as frequently that these practical values are of particular importance.

But the view of definite integrals which best shows their utility is the consideration of them as fundamental modes of expression. The ordinary symbols of algebra, it is well known, are incompetent to express in finite terms by far the greater number of integrals. Consequently the integrals themselves become modes of expression, and frequently the only ones. When we find a language with which we have much to do, and which has words which cannot be translated, we adopt the words of that language into our own. Precisely the same thing is done in the case of definite integrals. Thus, in FACTORIALS, we adopt the integral $\int_0^\infty \epsilon^{-x}x^n dx$, as the fundamental mode of expression for a function till then inexpressible, which becomes $1\ 2 \,.\, 3 \ldots n$ whenever n is an integer, and remains intelligible, though not very easily found, when n is a fraction.

Further to illustrate this, let us suppose that the integral calculus had made some progress before the conception of a logarithm had been formed: a thing which might easily have happened. It would then have been found that $\int x^{-1}dx$ was wholly unattainable, a function which algebra could not express in finite terms. It would therefore itself have become a mode of expression, and it would soon have been proved that

$$\int_1^a \frac{dx}{x} + \int_1^b \frac{dx}{x} = \int_1^{ab} \frac{dx}{x}.$$

Here then would have been an obvious indication of the existence of a function proper to be made use of in performing multiplication by means of addition, &c.; and tables of the values of $\int_1^a x^{-1}dx$ would have been formed by the method of quadratures [QUADRATURES,] or otherwise; which would, so it happens, have been a much easier task than that which fell on the first calculators of logarithms. For all this however it happens that we are prepared by knowing logarithms and their properties; so that $\int x^{-1}dx$ is seen to be log. $x + \mathrm{C}$, and $\int_1^a x^{-1}dx$ to be log. a: the logarithms throughout this article being Naperian. But we are not equally ready for $\int \epsilon^{-t^2}dt$, nor for $\int \epsilon^{-x}x^n dx$ (except when n is integer) nor for $\int \cos x^n dx$: and accordingly we are obliged to study the properties of these functions as fundamental modes of expression.

To give some idea of the use of this view, we exhibi a mode of solving the following partial differential equation,

$$\frac{du}{dt} = a\,\frac{d^2u}{dx^2},$$

the general solution of which cannot be expressed in finite terms. It will easily be seen that $c\epsilon^{\mu t+\nu x}$ is a solution for any value of c and ν, provided only that $\mu = a\nu^2$: and also that the sum of any number of such terms is a solution. Hence we assume an indefinite number of such terms giving to c the form $\phi\nu . d\nu$, and summing them with such values of ν as will make the whole represent

$$\int_p^q \phi\nu \,.\, \epsilon^{\nu x+a\nu^2 t}\, d\nu :$$

and we then see that this integral is a solution or general value of u, whatever the function $\phi\nu$ may be, and whatever may be the values of p and q. By a reduction which is rendered easy by some of the results presently mentioned, this solution is thrown into the form

$$u = \int_{-\infty}^{+\infty} \psi\,(x+2v\sqrt{at})\; \epsilon^{-v^2}\, dv,$$

where ψ may be the symbol of any function. From this it is clear that the given differential equation has numberless solutions which ordinary symbols are incapable of expressing in finite terms. The treatise in the Library of Useful Knowledge on the Differential Calculus, Gregory's 'Examples of the Differential Calculus,' and the 'Cambridge Mathematical Journal,' and its successor, contain various examples of this mode of expression applied to differential equations.

We now proceed to give a selection from the enormous number of definite integrals which has been given. They have been found by detached methods, so that we could not attempt to give anything more than the results. Our article is intended for reference to the forms which it is probable will be noted in future elementary works, and which the mathematical reader may also wish to refer to. In order to avoid risk of broken or dropped letters, in an article in which the correct printing of the limits is of the utmost importance, we shall print what is usually denoted by $\int_a^b \phi x dx$ in the following way, $\int \phi x dx\ [a, b]$. Any conditions as to the values of constants will be expressed before the integral. It need hardly be said that the article FACTORIALS must be considered as a part of the present one.

Among the integrals which clearly depend on, or are connected with, factorials, are the following :—

$$(m+1<n) \int \frac{x^m dx}{1+x^n}\ [0, \infty] = \frac{\pi}{n \sin\left(\frac{m+1}{n}\pi\right)}$$

$$(m+1<n) \int \frac{x^m dx}{(1+x)^n}\ [0, \infty] = \frac{\Gamma(m+1)\ \Gamma(n-m-1)}{\Gamma n}$$

$$(m \text{ and } n \text{ positive})\ \int x^{m-1}(1-x)^{n-1} dx\ [0, 1] = \frac{\Gamma m \,.\, \Gamma n}{\Gamma(m+n)}$$

$$\int \frac{x^{m-1}(1-x)^{n-1}}{(x+a)^{m+n}}\, dx\ [0, 1] = \frac{\Gamma m \,.\, \Gamma n}{a^n (1+a)^m\ \Gamma(m+n)}$$

$$(n \text{ positive}) \int (-\log x)^{n-1} dx\ [0, 1] = \Gamma n$$

$$(m \text{ and } n \text{ positive}) \int x^{m-1}\,(-\log x)^{n-1}\, dx\ [0, 1] = m^{-n}\,\Gamma n$$

$$(a \text{ and } n \text{ positive}) \int x^{n-1}\,\epsilon^{-ax}\, dx\ [0, \infty] = a^{-n}\Gamma n$$

$$(n \text{ positive}) \int \epsilon^{-x^n}\, dx\ [0, \infty] = \frac{1}{n}\ \Gamma\ \frac{1}{n}$$

$$\int \epsilon^{-x^2} dx\ [0, \infty] = \tfrac{1}{2}\sqrt{\pi}.$$

Tables of the value of $(2 : \sqrt{\pi}) \int \epsilon^{-x^2} dx\ [0, a]$, which are of great importance in the theory of probabilities, are given in modern works on that subject. The following expression by means of a continued fraction is useful. Let $q = 1 : 2a^2$, then

$$\int \epsilon^{-x^2} dx\ [a, \infty] = \frac{\epsilon^{-a^2}}{2a}\ \frac{1}{1+}\ \frac{q}{1+}\ \frac{2q}{1+}\ \frac{3q}{1+}\ \frac{4q}{1+}\ \&c.$$

$$(n>-1) \int \frac{1-x^n}{1-x}\, dx\ [0, 1] = \gamma + \frac{d \log \Gamma(1+n)}{dn};$$

γ being as in FACTORIALS.

One of Euler's integrals, generally called the second Eulerian integral, the factorial integral being the first, he denoted by the symbol

$$\left(\frac{n}{m}\right);\ \text{it is} \int x^{n-1}(1-x^k)^{\frac{m}{k}-1} dx\ [0, 1],$$

and it is included in those already given.

There is a class of multiple integrals closely connected with factorials, which may be made to save much trouble in applications to geometry. We shall take three variables as a specimen, but the same formulæ may be written with any number. The triple integration being made for all positive values which give $x+y+z$ not exceeding l, we have (a, b, c, being positive)

$$\int x^{a-1}\,y^{b-1}\,z^{c-1}\, dxdydz = \frac{\Gamma a \,.\, \Gamma b \,.\, \Gamma c}{\Gamma(a+b+c+1)}\ l^{a+b+c}$$

$$\int x^{a-1}\,y^{b-1}\,z^{c-1} f(x+y+z)\, dxdydz$$

$$= \frac{\Gamma a \,.\, \Gamma b \,.\, \Gamma c}{\Gamma(a+b+c)} \int x^{a+b+c-1} fx dx\ [0, l]$$

Similarly, the condition being that

$$\left(\frac{x}{P}\right)^p + \left(\frac{y}{Q}\right)^q + \left(\frac{z}{R}\right)^r$$

shall not exceed l, we have

$$\int x^{a-1}y^{b-1}z^{c-1} \int \left\{\left(\frac{x}{P}\right)^p + \left(\frac{y}{Q}\right)^q + \left(\frac{z}{R}\right)^r\right\} dxdydz$$

$$= \frac{P^a Q^b R^c}{pqr}\ \frac{\Gamma\frac{a}{p} \cdot \Gamma\frac{b}{q}\ \Gamma\frac{c}{r}}{\Gamma\left(\frac{a}{p}+\frac{b}{q}+\frac{c}{r}\right)} \int x^{\frac{a}{p}+\frac{b}{q}+\frac{c}{r}-1}\ fx dx\ [0, l].$$

We shall now give some specimens of the results of functions involving trigonometrical quantities. One of the most important of this class is the following :—

$$\int x^{-1} \sin bx\, dx\ [0, \infty] = \pm \tfrac{1}{2}\pi$$

according as b is positive or negative.

$$(a \text{ pos}) \int \frac{\cos ax\ dx}{1+x^2}\ [0, \infty] = \int \frac{\sin ax \,.\, x dx}{1+x^2}\ [0, \infty] = \frac{\pi}{2}\ \epsilon^{-a}$$

$$\int \epsilon^{-ax} \cos bx dx\ [0, \infty] = a : (a^2+b^2)$$

$$\int \epsilon^{-ax} \sin bx dx\ [0, \infty] = b : (a^2+b^2) :$$

from these come

$$\int \cos bx dx\ [0, \infty] = 0,\ \int \sin bx dx\ [0, \infty] = 1;$$

and from these come two equations which have been much used, long before they were openly expressed,

$$\sin \infty = 0,\ \cos \infty = 0.$$

Some difference of opinion exists about these equations, which in fact involve a great deal of what has been done by mathematicians[*] in the last thirty years.

When a and n are both positive

$$\int \epsilon^{-ax} \cos bx \,.\, x^{n-1} dx\ [0, \infty] = \frac{\Gamma n \,.\, \cos\left\{n \tan^{-1}(b : a)\right\}}{(a^2+b^2)^{\frac{n}{2}}}$$

$$\int \epsilon^{-ax} \sin bx \,.\, x^{n-1} dx\ [0, \infty] = \frac{\Gamma n \,.\, \sin\left\{n \tan^{-1})b : a)\right\}}{(a^2+b^2)^{\frac{n}{2}}}$$

$$\int \cos x^m \,.\, x^n dx\ [0, \infty] = \frac{1}{m}\ \Gamma\left(\frac{n+1}{m}\right) \cos\left(\frac{n+1}{2m}\pi\right)$$

$$\int \sin x^m \,.\, x^n dx\ [0, \infty] = \frac{1}{m}\ \Gamma\left(\frac{n+1}{m}\right) \sin\left(\frac{n+1}{2m}\pi\right)$$

$$a<b \int \frac{\sin ax}{\sin bx}\ \frac{dx}{1+x^2}\ [0, \infty] = \frac{\pi}{2}\ \frac{\epsilon^{a}-\epsilon^{-a}}{\epsilon^{b}-\epsilon^{-b}}.$$

But when $a = 2mb \pm c$, m being an integer, the preceding integral is

$$\frac{\pi}{2}\ \frac{\epsilon^{c}+\epsilon^{-c}-2\epsilon^{-a}}{\epsilon^{b}-\epsilon^{-b}}.$$

This is a specimen of a sort of discontinuity which very frequently occurs, and from not attending to which mistakes have often arisen.

If we call $\frac{1}{2}(\epsilon^x + \epsilon^{-x})$ and $\frac{1}{2}(\epsilon^x - \epsilon^{-x})$ the *hyperbolic* cosine and sine of x, and denote them by h. cos x and h. sin x, we have, the limits being 0 and ∞, and a being less than π,

$$\int \frac{\text{h. } \sin ax}{\text{h. } \sin \pi x} \cos cx\ dx = \frac{1}{2}\ \frac{\sin a}{\cos a + \text{h. } \cos c}$$

$$\int \frac{\text{h. } \cos ax}{\text{h. } \cos \pi x} \cos cx\ dx = \frac{\cos \frac{1}{2}a \,.\, \text{h. } \cos \frac{1}{2}c}{\cos a + \text{h. } \cos c}$$

$$\int \frac{\text{h. } \cos ax}{\text{h. } \sin \pi x} \sin cx\ dx = \frac{1}{2}\ \frac{\text{h. } \sin c}{\cos a + \text{h. } \cos c}$$

$$\int \frac{\text{h. } \sin ax}{\text{h. } \cos \pi x} \sin cx\ dx = \frac{\sin \frac{1}{2}a \,.\, \text{h. } \sin \frac{1}{2}c}{\cos a + \text{h. } \cos c}$$

$$\int \frac{\sin cx\, dx}{\epsilon^{2\pi x}-1}\ [0, \infty] = \frac{1}{4}\ \frac{\epsilon^{c}+1}{\epsilon^{c}-1} - \frac{1}{2c}.$$

The integral $4n \int \frac{t^{2n-1}\, dt}{\epsilon^{2\pi t}-1}\ [0, \infty]$ is the nth number of Bernoulli [NUMBERS OF BERNOULLI], meaning that opposite to which $2n-1$ is written in the article cited.

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[*] With regard to these equations, it must be observed that they are not to have their algebraical consequences; thus, $\sin^2 \infty$ is not 0, but $\frac{1}{2}$. The truth seems to be, as far as yet appears, that any function ϕx, which becomes indefinite in form, by the angle x becoming infinite, is properly represented by $\int \phi x dx$ [0, 2π] divided by 2π.

As specimens of the reduction of definite integrals, the integrals

$$\int\frac{\epsilon^{-a^2t^2}\cos axt\,dt}{1+t^2}\,[0,\infty]\text{ and }\int\frac{\epsilon^{-a^2t^2}\sin axt\,tdt}{1+t^2}\,[0,\infty]$$

are severally equal to

$$\frac{\sqrt{\pi}\,.\,\epsilon^{a^2}}{2}\Big\{\epsilon^{-ax}\int\epsilon^{-t^2}dt\,[-\infty,\tfrac{1}{2}x-a]$$

$$\pm\,\epsilon^{ax}\int\epsilon^{-t^2}dt\,[\tfrac{1}{2}x+a,\infty]\Big\}$$

the first having $+$, the second $-$. Also

$$\int\frac{\epsilon^{-a^2t^2}dt}{1+t^2}\,[0,\infty]=\sqrt{\pi}\,.\,\epsilon^{a^2}\int\epsilon^{-t^2}dt\,[a,\infty].$$

The following is fundamentally important,

$$\int\epsilon^{-a^2x^2}\cos bxdx\,[0,\infty]=\frac{\sqrt{\pi}}{2a}\,\epsilon^{-\frac{b^2}{4a^2}}$$

The integral $\int\frac{dx}{\log x}\,[0,a]$ has been tabulated [Diff. Calc., L. U. K., p. 662] by Soldner, and a great many integrals may be found from it. Soldner proposes to call it the *Logarithm-integral* of a, and to denote it by the abbreviation li. a. Adopting this notation, we have then, both in definite and indefinite forms,

$$\int\frac{x^m dx}{\log x}=\text{li. }x^{m+1}\qquad\int\frac{\epsilon^{\pm x}dx}{x}=\text{li. }\epsilon^{\pm x}$$

$$\int\frac{dx}{\log(a+bx)}=\frac{1}{b}\text{li. }(a+bx)\quad\int\epsilon^{\epsilon^x}dx=\text{li. }\epsilon^{\epsilon^x}$$

and so on.

Of miscellaneous integrals there is an immense number, of which we give a few instances:—

$$\int\frac{(1-v^m)(1-v^n)\,dv}{(1-v)\log v}\,[0,1]=\log\frac{\Gamma(1+m\,\Gamma(1+n)}{\Gamma(1+m+n)}$$

$$(a\text{ pos.})\int\frac{x\tan x\,dx}{a^2+x^2}\,[0,\infty]=\frac{\pi}{\epsilon^{2a}+1}$$

$$(a\text{ pos.})\int\frac{x\cot xdx}{a^2+x^2}\,[0,\infty]=\frac{\pi}{\epsilon^{2a}-1}$$

$$(a\text{ pos.})\int\epsilon^{-ax}\sin bx\,.\,x^{-1}dx\,[0,\infty]=\tan^{-1}\,(b:a)$$

$$\int\frac{\epsilon^{-ax}\cos bx-\epsilon^{-\alpha x}\cos\beta x}{x}dx\,[0,\infty]=\frac{1}{2}\log\frac{\alpha^2+\beta^2}{a^2+b^2}$$

if neither α nor a be negative.

$$\int\epsilon^{-x^2-\frac{a^2}{x^2}}dx\,[0,\infty]=\frac{1}{2}\sqrt{\pi}\,\epsilon^{-2a}$$

$$\int\frac{x\sin x\,dx}{1-2a\cos x+a^2}\,[0,\pi]=\frac{\pi}{a}\log(1+a)\text{ or }\frac{\pi}{a}\log\left(1+\frac{1}{a}\right)$$

according as a is less or greater than unity.

Among the means of producing or using definite integrals which are comprehensive enough to deserve the name of methods, there are four which particularly deserve the attention of elementary writers.

The first is Laplace's mode of finding the approximate value of a definite integral in which large constant exponents occur. Let ϕx be a function of x, such as $\epsilon^{-x}x^n$ or $x^n.(1-x)^m$, &c., in which n, m, &c., are considerable exponents. Let this function vanish when $x=a$ and $x=b$, and, continuing positive and finite throughout the interval, let it come to its maximum Y, when $x=\mathrm{X}$. Let v_2 mean the value of the second differential coefficient of $\log\phi x$, when $x=\mathrm{X}$, and assume $\phi x=\mathrm{Y}\epsilon^{-t^2}$. Then

$$\int\phi x\,dx=\mathrm{Y}\sqrt{\left(-\frac{2}{v_2}\right)}\int\epsilon^{-t^2}dt\text{ nearly,}$$

provided that the limiting values of t on the second side are those which, in the equation of $\phi x=\mathrm{Y}\epsilon^{-t^2}$, belong to the limiting values of x taken on the first side. The best approximating cases are as follows:—First, when a and b are the limiting values of x, in which case $-\infty$ and $+\infty$ are those of t, and the result is

$$\int\phi x\,dx\,[a,b]=\mathrm{Y}\sqrt{\left(-\frac{2}{v_2}\right)}.\sqrt{\pi}.$$

Secondly, when the limiting values of x are $\mathrm{X}\pm\xi$, ξ being small. In this case

$$\int\phi x\,dx\,[\mathrm{X}\pm\xi]=\mathrm{Y}\sqrt{\left(-\frac{2}{v_2}\right)}\,2\int\epsilon^{-t^2}dt\left[0,\xi\sqrt{\left(-\frac{v_2}{2}\right)}\right]$$

This method is found, by itself, almost sufficient to meet the wants of the more complicated problems in the theory of probabilities.

Secondly, Fourier's theorem, as it is usually called, by which a discontinuous function can be expressed. This theorem is as follows:—

$$\phi x=\frac{1}{\pi}\iint\cos w(x-v)\,.\,\phi v\,.\,dwdv,$$

from $v=-\infty$ to $x=+\infty$, and from $w=0$ to $w=\infty$. Or thus, the equation

$$\phi x=\frac{1}{\pi}\int_0^\infty\int_{-\infty}^{+\infty}\cos w(x-v)\,.\,\phi v\,.\,\epsilon^{-kw}dwdv$$

is one which, for all values of x, approaches without limit to truth, as k is diminished without limit positively. But if, instead of the limits $-\infty$ and $+\infty$, for v, we write a and b, a being less than b, then

$$\frac{1}{\pi}\int_0^\infty\int_a^b\cos w(x-v)\,.\,\phi vdwdv$$

is a discontinuous function, as follows:—From $x=-\infty$ to $x=a$ exclusive, it is nothing; when $x=a$, it is $\frac{1}{2}\phi a$; from $x=a$ to $x=b$ both exclusive, it is ϕx; when $x=b$, it is $\frac{1}{2}\phi b$; and from $x=b$ to $x=\infty$ it is nothing.

Thirdly, the following methods of expanding a function in series of sines and cosines has been extensively used by Lagrange, Poisson, and Fourier. We give it in the most general form after the manner of Poisson. Let

$$\phi x=\mathrm{A}_0+\mathrm{A}_1\cos\frac{\pi x}{l}+\mathrm{A}_2\cos\frac{2\pi x}{l}+\ldots$$

then, for every value of x from $x=0$ to $x=l$, both inclusive, this equation is true if

$$\mathrm{A}_0=\frac{1}{l}\int\phi vdv\,[0,l],\ \mathrm{A}_m=\frac{2}{l}\int\cos\frac{m\pi v}{l}\,\phi vdv[0,l].$$

Again, the equation

$$\phi x=\mathrm{B}_1\sin\frac{\pi x}{l}+\mathrm{B}_2\sin\frac{2\pi x}{l}+\ldots.$$

is true from $x=0$ to $x=l$, both exclusive, if

$$\mathrm{B}_m=\frac{2}{l}\int\sin\frac{m\pi v}{l}\,\phi vdv[0,l].$$

Further, the equation

$$\phi x=\mathrm{A}_0+\mathrm{A}_1\cos\frac{\pi x}{l}+\mathrm{A}_2\cos\frac{2\pi x}{l}+\ldots.$$

$$+\,\mathrm{B}_1\sin\frac{\pi x}{l}+\mathrm{B}_2\sin\frac{2\pi x}{l}+\ldots.$$

is true for all values of x from $x=0$ to $x=l$, both exclusive (becoming $\frac{1}{2}\phi l$ when $x=l$), if

$$\mathrm{A}_0=\frac{1}{2l}\int\phi vdv[0,l],\ \mathrm{A}_m=\frac{1}{l}\int\cos\frac{m\pi v}{l}\,\phi vdv[0,l]$$

$$\mathrm{B}_m=\frac{1}{l}\int\sin\frac{m\pi v}{l}\phi vdv[0,l].$$

But write $2l$ instead of l, *in the limits only*, or write $[0,2l]$ instead of $[0,l]$, and the equation becomes true for all values of x from 0 to $2l$, both inclusive.

Fourthly, we shall give two cases of the method deduced by Cauchy, as specimens: the complete method itself has some difficulties which are not yet overcome.

First, let ϕx be such a function of x that $\phi(x+y\sqrt{-1})$ vanishes when $x=-\infty$ or $+\infty$, whatever y may be, and when y equals ∞, whatever x may be. For every root of the form $a+b\sqrt{-1}$ (a being either positive or negative, and b being positive, but both finite) which makes ϕx infinite, let $(x-a-b\sqrt{-1})\phi x$ be finite; calculate the value of this last product for each root. For every real root a, of $\phi x=\infty$ ($x=0$ not being one) calculate half the value of $(x-a)\,\phi x$. Let the sum of all these values and half values be P. Then

$$\int\phi xdx[-\infty,+\infty]=2\pi\sqrt{-1}\,.\,\mathrm{P}.$$

Secondly, let ϕx be such a function that $\phi(x+y\sqrt{-1})$ vanishes when $x=+\infty$ or $-\infty$ independently of y, and when $y=+\infty$ or $-\infty$ independently of x. Take the imaginary roots only which make ϕx infinite, and let $(x-a-b\sqrt{-1})\phi x$ be always finite when $a+b\sqrt{-1}$ is one of those roots, and $x=a+b\sqrt{-1}$. Let the sum of all the values of the last product, for the cases in which b is positive, be P; and for the cases in which b is negative let it be Q. Then

$$\int\phi xdx[-\infty,+\infty]=\pi\sqrt{-1}\,.\,(\mathrm{P}-\mathrm{Q}).$$

The subject of definite integrals is one in which the difficulties which have always appeared at the boundaries of mathematical knowledge are constantly met with. The consequence is, considerable difference of opinion about many points. On these, the student who desires to use the higher parts of analysis must hope to form his opinion independently, when his reading and reflection are sufficient for the purpose. Most of these difficulties belong, in principle, to that which accompanies the use of divergent series, which is the most important mathematical question now under discussion. If we were to judge of the future by the past, we should prophesy that divergent series would one day take their undisputed place among well understood objects of analysis, as negative quantities and their logarithms, imaginary quantities and their exponentials, infinitely small quantities with their different orders, discontinuous solutions of differential equations, &c., have successively done, each under a fire of objections which has well served the progress of science, by the defensive researches which it has rendered necessary. It is fortunate for analysis that so many of those who find difficulties propose the entire rejection of the symbols or methods in which the difficulties exist: the proposition excites those who are against any rejection to efforts which they perhaps would not make, if they had only to meet the doubts of allies, instead of the attacks of opponents. That the symbolic expressions of which we are speaking will never vanish out of remembrance, we may confidently predict: of all the points of difficulty of which we have spoken, it may be said, in the words of Horace—

> "Naturam expelles furcâ, tamen usque recurret;"

they will come, and will demand explanation until they get it. They will conquer by numbers, as Fontenelle said the symbol of infinity had done. And it is to be hoped and expected that no difficulty will be completely resolved, without the appearance of a successor, to excite new efforts, and be the stimulating cause of further progress. We should be sorry to think we had arrived at the "last impossibilities[*] of pure mathematics." A very valuable accession to the literature of definite integrals has been recently made by Mr. Bierens de Haan, who has filled the fourth volume of the 'Transactions of the Royal Academy of Sciences of Amsterdam' with a list of definite integrals, with their values, and references to the authors who have given them. The list occupies 550 quarto pages.

INTEGRATION, FINITE. By this term is meant the summation of any number of terms of a series which follows a regular law; and just as INTEGRATION was reduced in a preceding article to the determination of a function from its differential coefficient, so finite integration or summation may be reduced to the determination of a function from its difference. [DIFFERENCE.]

First, let there be a function of x, ϕx, and let x successively become $x+\Delta x$, $x+2\Delta x$ .... up to $x+(n-1)\Delta x$, so that n different values are given to x. It is required to sum the series

$$\phi x+\phi(x+\Delta x)+\phi(x+2\Delta x)+\ldots+\phi(x+\overline{n-1}\Delta x)$$

Let $x=v\Delta x$, and let $\phi(v\Delta x)$ be called ψv. Then the series becomes

$$\psi v+\psi(v+1)+\psi(v+2)+\ldots\ldots+\psi(v+n-1)$$

This sum is a function of n, and such, that if n be changed into $n+1$, one more term $\psi(v+n)$ will be added: consequently it must be the function which has $\psi(v+n)$ for its difference. If, then, we denote the preceding sum by $\Sigma\psi(v+n)$, we find

$$\Delta\left\{\Sigma\psi(v+n)\right\}=\psi(v+n)$$

or Δ and Σ express operations which are inverse to one another. Remark that the symbol Σa does not denote the sum of a number of terms up to a inclusive, but up to a exclusive: thus

$$1+2+3+\ldots\ldots+(n-1) \text{ is } \Sigma n$$
$$1+2+3+\ldots\ldots+(n-1)+n \text{ is } \Sigma(n+1)$$

All that precedes has no reference to the term with which we begin: thus $4+5+\ldots\ldots+n$ and $1+2+3+4+5+\ldots\ldots+n$ are equally denoted by $\Sigma(n+1)$. This symbol is therefore indefinite, but it will be found that the process by which it is to be determined gives an indefinite result.

Suppose, for instance, we have ascertained that $\frac{1}{2}(n^2+n)$ is the function whose difference is $(n+1)$, which will be found to be the case; or

$$\tfrac{1}{2}\left\{(n+1)^2+(n+1)\right\}-\tfrac{1}{2}\left\{n^2+n\right\}=n+1.$$

It is equally true that $\frac{1}{2}(n^2+n)+C$ has $n+1$ for its difference, where C may be anything whatever, provided that it do not change when n changes. Hence

$$\Sigma(n+1)=\tfrac{1}{2}(n^2+n)+C;$$

but a being any whole number less than n, $\Sigma(n+1)$ may stand for $a+(a+1)+\ldots\ldots+n$. Consequently C in the one must be taken in a manner corresponding to a in the other. If n were equal to a, the series would be reduced to one term a, and $\frac{1}{2}(n^2+n)+C$ would become $\frac{1}{2}(a^2+a)+C$. Determine C so that these shall be equal: we have then to make

$$a=\tfrac{1}{2}(a^2+a+C,\ C=-\tfrac{1}{2}(a^2-a)$$
$$a+(a+1)+\ldots\ldots+n=\tfrac{1}{2}(n^2+n)-\tfrac{1}{2}(a^2-a).$$

The inverse method of differences, or that of finite integration, is founded upon the preceding principles and notation: but so far as the mere summation of simple series is concerned, the following rules will be sufficient:—

1. Let a be the first term of a series of n terms, a, b, c, &c. Form the successive differences of a [DIFFERENCE], which will all vanish after a certain point in every instance to which this rule applies. Then the sum of the n terms is

$$na+n\frac{n-1}{2}\Delta a+n\frac{n-1}{2}\frac{n-2}{3}\Delta^2 a+\ldots\ldots$$

EXAMPLE:	1 + 8 + 27 + 64 + 125 + ... + n^3
First diff.	7 19 37 61 ....
Second diff.	12 18 24 ....
Third diff.	6 6 ....
Fourth diff.	0 0 ....

Here $a=1$, $\Delta a=7$, $\Delta^2 a=12$, $\Delta^3 a=6$, $\Delta^4 a=0$, $\Delta^5 a=0$, &c.

and the sum required is

$$n+7n\frac{n-1}{2}+12n\frac{n-1}{2}\frac{n-2}{3}+6n\frac{n-1}{2}\frac{n-2}{3}\frac{n-3}{4}$$

It may be convenient to give the reduction of the preceding formula in the cases where all after the second differences vanish, and the same for the third. Let a', a'', a''', &c., be the differences of a; when $a'''=0$, $a^{\text{iv}}=0$, &c., the sum is one-sixth of

$$a''n^3+(a'-a'')3n^2+(6a-3a'+2a'')n.$$

When $a^{\text{iv}}=0$, $a^{\text{v}}=0$, &c., the sum is one twenty-fourth of

$$a'''n^4+\text{P}n^3+\text{Q}n^2+\text{R}n$$

where $\text{P}=4a''-6a'''$
$\text{Q}=12a'-12a''+11a'''$
$\text{R}=24a-12a'+8a''-6a'''$

2. Let there be a number of terms in uniformly increasing progression, such as 4, $4\frac{1}{2}$, 5, $5\frac{1}{2}$, &c.; and let a series be formed by multiplying a number of terms from the beginning, then the same number from the second, and so on, as in

$$3.4.5+4.5.6+5.6.7+\ldots\ldots+12.13.14$$

To find the sum of this series, put an additional factor at the end of the last term and at the beginning of the first term; subtract the latter from the former, and divide by the common difference of the successive factors taken one more time than there are factors in each term. Thus the sum of the preceding is 12.13.14.15 — 2.3.4.5 divided by 1 taken 4 times. Again

$$1.2+2.3+3.4+4.5+5.6$$

is 5.6.7 — 0.1.2 divided by 1 taken 3 times; or 70; as may easily be verified. Also

$$1.3+3.5+5.7+7.9$$

is 7.9.11 — (— 1) 1.3 divided by 2 taken 3 times; or 116.

3. Let the series consist of reciprocals of terms like the preceding: as

$$\frac{1}{3.4.5}+\frac{1}{4.5.6}+\ldots\ldots+\frac{1}{12.13.14}$$

To sum this series, strike off a factor from the end of the first term and the beginning of the last term; subtract the second from the first, and divide by the common difference of the successive factors taken one time less than there are factors in each denominator. Thus the sum of the preceding terms is

$$\frac{1}{3.4}-\frac{1}{13.14} \text{ divided by 1 taken twice}$$

Similarly $\frac{1}{1.3}+\frac{1}{3.5}+\frac{1}{5.7}$ is $\frac{1}{1}-\frac{1}{7}$ divided by 2 taken once; or $\frac{3}{7}$, as may easily be verified.

INTELLECT (*intellectus*), that which perceives and understands, comprehending all the cognitive powers of the mind, in contradistinction to the active powers or the will. "The internal and immanent acts of the reasonable soul (besides those of common sense, phantasy, memory, passion and appetite, common to man and inferior animals) are intellect and will, and the proper acts of these are intellection, deliberation, and determination, or decision." (Hale's 'Origin of Mankind.') In the Aristotelian philosophy the intellect (νοῦς) first works on the phantasms, and discerns by a spontaneous energy what in many is one, what in things dissimilar is similar and the same (τὸ δὲ ἓν ποιοῦν τοῦτο ὁ νοῦς ἕκαστον). By this means it attains to a new kind of perceptions (εἴδη), more comprehensive than those of sense; and each of these general ideas subsists entire in each individual of an infinite multitude without losing its own unity and permanence. On the other hand it is the source of those primary principles on which all science rests, as conversant about universal and demonstrable truth.

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[*] These are the words of Mr. A. F. Vogel, of Leipsic, who published in this country a tract on the resolution of all kinds of equations, printed at Leipsic in his own English.

For intellect Mr. Stewart prefers the vernacular term understanding, which he employs in the same extensive signification. But the critical philosophy of Kant distinguishes the intellect into two faculties, understanding and reason. The understanding acting on experience merely compares, judges, and measures its representations, and is conversant solely with their mutual limits and relations, classifying them according to certain schemes of its own which are called categories. While however the understanding is thus limited, the activity of the reason is unbounded, and, as the principle of principles, it is the base and the verification of every special principle and reasoning.

Intellectualism, or intellectual philosophy, as opposed to sensualism, is a particular theory in philosophy, according to which the intellect or thought is the only source of true knowledge, whereas the evidence of sense is but a cheat and delusion. The Eleatæ were the most distinguished adherents of this doctrine. The phrase intellectual knowledge denotes whatever principle or proposition had its origin in the understanding or reason, as opposed to sensuous or empirical knowledge, whose source is sensation. As contradistinguished from sensibles, the objects of this cognition are denominated intelligibles (*αισθητά, νοητά*).

INTERCALARY. [KALENDAR.]

INTERDICT (*Interdictum* in the Roman law). The general distinction between the Roman Interdictum and Actio seems clearly pointed out by Savigny in a few remarks on the passage in Gaius (iv. 139), where that writer treats of the interdict. The words of Gaius, which form the groundwork of the following remarks of Savigny, are: "Certis ex caussis Prætor aut Proconsul *principaliter* auctoritatem suam finiendis controversiis proponit" (or *præponit*, as Haubold reads, after Maffei); and his remarks have reference to the supposed difficulty of the word *principaliter*, and to a certain proposed emendation supported by very indifferent reasons.

The general distinction between the actio and the interdictum is this: in the actio the prætor does nothing, but only allows a *judex*, whose duty it is to inquire and decide. When the *judex* has decided, the matter may in general be considered as at an end, and if the prætor is again called on to act in the cause, such must be viewed as an accidental thing. This appears from the terms of the prætor's order in matters which belong to the actio: he does not command or forbid a thing to be done, but he says "judicium dabo." With the interdictum it is just the reverse. Here also *judices* or *recuperatores* may be required when the facts are in dispute; but as a general rule in matters to which the interdict applies, the case is such that the prætor's order can immediately terminate the question. The prætor accordingly does not say "judicium dabo," but he uses the ordering words "restituas, exhibeas, vim fieri veto," &c.; and this could not be better expressed, as Savigny remarks, than by the words "principaliter," &c.; the meaning of which, as Haubold observes, can hardly be anything else than this: "the prætor or the proconsul at once gives a definitive judgment, by which the dispute, at least for the present, is terminated."

According to Gaius, the general description of the interdictum is this—it ordered something to be done, or forbade something being done. The forms of the orders used on such occasions were called by the general name of interdicta. When the order was to produce something (exhibere), or restore a thing (restituere), the interdicta were called Decreta. The term Interdictum was used when the order forbade a certain thing being done—as disturbing a man who was in possession, *sine vitio*; preventing any trespass on sacred ground, &c.

The general process seems to have been by a kind of bill or petition addressed to the prætor, in which the plaintiff stated his grievance and prayed for redress, that is, for the interdictum. The defendant also stated his case, probably by way of reply to that of the plaintiff. If the case was clear on the part of the plaintiff, he obtained the interdict. Or if the defendant admitted the plaintiff's statement of his case, or if after the interdict was obtained he submitted to its terms, the matter was at an end. If the defendant denied the plaintiff's case, that is, denied that there was any ground for the interdict, or maintained that he had given the plaintiff full satisfaction, and had complied with the terms of the interdict, the plaintiff made his application to the prætor to refer the matter to *judices* or *recuperatores*, or to an *arbiter*. The parties complainant and defendant went before the *judex* or *arbiter* whom the prætor named, and the process then became the usual process of the actio. The parties produced their witnesses and proofs, and the judex or arbiter decided upon them. The terms of the interdict, in case it was prohibitory, were the formal words of the edict which determined in what cases such relief could be given (certis ex caussis), only so far varied as to apply to the parties who were in dispute. In the restitutory and exhibitory interdict, the terms of the order would necessarily vary according to circumstances. If the matter came before a *judex*, the only question as to the prohibitory interdict which he had to settle was, whether the defendant had, by his acts, brought himself within the prætor's interdict. If he had, the interdict must be enforced against him; if not, it must be dissolved. In the case of the restitutory and exhibitory interdict coming before the *judex* or *arbiter*, the matters for inquiry would be—whether the defendant had, by his acts, given good ground for the interdict; whether he had satisfied the terms of the interdict; what damages the defendant should pay to the plaintiff, in case he had not satisfied the terms of the interdict, or had only satisfied them imperfectly. If no *sponsio* (deposit of money by the parties abiding by the result of the inquiry) had been entered into, and consequently the matter had come before an *arbiter*, all these three points had to be determined, and the damages were at the discretion of the *arbiter*; in case there was a sponsio (which in the prohibitory interdict was necessary, but in the other interdicts not absolutely necessary), the *judices* or recuperatores had to determine only the first two points. (Cicero, 'Pro Cæcina,' 8.) In fact, when the matter came before a *judex* or *arbiter* the interdict process did not differ from that of the ordinary actio, as appears from Cicero's oration 'Pro Cæcina,' in which the plaintiff Cæcina had obtained the prætor's interdict 'Unde Tu,' &c., against the defendant Æbutius, and the matter had been referred to recuperatores. The defence of Æbutius before the recuperatores was, that he had obeyed the interdict and had restored the plaintiff to the same place from which he had ejected him. The defendant had not in fact done this; but it appears to have been sometimes the formal way of raising the question, whether the act complained of had been committed. If it was not committed, the defendant had in substance obeyed the interdict, that is, had not acted contrary to it. Mr. Spence, in his work on the 'Equitable Jurisdiction of the Court of Chancery,' has given a short account of this branch of the Roman law of procedure; and in that part of his book where the history of the rise and progress of the English chancellor's jurisdiction by injunction is discussed (vol. i., ch. xxii.), he maintains that the Roman jurisprudence afforded a model from which a system might be constructed that should supply the desired means for protecting property against actual or prospective dangers. But as he shows, the application of the principle thus introduced was extended much beyond the limits of the Roman process, and the clerical chancellors and their lay successors gradually made great improvements in the method of carrying out the system they had thus introduced.

The authorities for what is above stated are: Haubold, *Ueber die Stelle von den Interdicten in den Veronesischen Handschriften*; and Savigny, C., *Nachträgliche Bemerkungen*, in the *Zeitschrift für geschichtliche Rechtswissenschaft*, Ser band. For the application of the interdict to the case of possession, Savigny, *Das Recht des Besitzes*, translated into English by Sir Erskine Perry (book iv.), should be consulted, and his remarks on the case of Cæcina. And in Niebuhr's *History of Rome*, English translation, edit. 1851, vol. ii., p 180, the reader will find a very able sketch of this intricate and obscure part of Roman legal history. The valuable work of Brissonius, *De Formulis*, lib. v., c. 154, contains a collection of passages which refer to the functions of the judex in the interdict process; and for the actual text of the Roman law on this subject the reader is referred to the *Commentaries of Gaius*, iv., § 138; Justinian's *Institutes*, book iv., title 15, § 170; and *Digest*, book xliii. [INJUNCTION.]

INTERDICT, in the law of Scotland, is a proceeding in the nature of an injunction from a court of equity in England. It is a prohibitory order, forbidding some act from being done, and it is obtained on the application of the party who would be injured by the performance of the act. It may be issued by the Court of Session, or by the Sheriff's Court. Interdicts also occupy in the law of Scotland a place analogous to the writ of prohibition in England. They are frequently obtained for preventing inferior courts, or courts of limited operation, from exceeding their jurisdiction. To this end the form has been frequently adopted in the disputes between different parties in the Church of Scotland. In pressing matters, interim interdict is awarded before the parties are heard, but in the general case intimation is given to the other party, who gives in answers, and the matter proceeds as an ordinary litigation.

INTERDICT, ECCLESIASTICAL, a mode of censure employed at times by the Roman Catholic church, by which, in consequence of some offence alleged to have been committed by the people or rulers of a town or country, the pope forbade by a bull the performance of any kind of church rites within the same; the church-service was suspended, the sacraments were not administered, and the funeral service was not read. The use of interdicts appears to have originated with the bishops of the 9th century. Hincmar, bishop of Laon in France, laid a parish of his diocese under an interdict in the year 870. (Moreri's 'Dictionary,' art. 'Interdict.') In the middle ages this measure was often resorted to by the popes in consequence of some serious dispute with the sovereigns of particular countries, and it had the effect of throwing whole kingdoms into consternation, and even into a state of rebellion, by which the refractory sovereigns were obliged to sue for pardon from the pontiff. Gregory VII. and Innocent III. made free use of the interdict. Adrian IV. laid Rome itself under an interdict for the purpose of driving away Arnaldo da Brescia and his followers. Some popes mitigated the rigour of the interdict out of regard to the spiritual wants of the people, who could not be justly punished for the guilt of their rulers. Gregory IX., during the interdict against Frederic II., allowed mass to be said on Sundays. On some occasions the sacrament to the dying and baptism to infants were allowed to be administered. (See Lyndwood.)

The frequent abuse of the interdict has been censured even by Roman

Catholic writers. In course of time the measure was found no longer to answer its object, and it became of rare occurrence. Paul V., in April, 1606, laid the republic of Venice under an interdict, because the senate had decreed that no more convents should be founded, and no more property should be bequeathed to monastic orders without permission from the government. The senate forbade the bull of interdict to be published in the territories of the republic, and ordered the parochial clergy to continue the exercise of their sacred ministry as usual. The Jesuits, Franciscans, and other monks pleaded their duty of obedience to the see of Rome, and the senate told them that they might depart, which they did. At last, in 1607, through the mediation of Henry IV. of France, the pope removed the interdict, which had produced little or no effect on the minds of the Venetian people.

INTEREST, money which is paid for the use of other money, the lender stipulating for a fixed sum to be paid yearly, half-yearly, or quarterly, for each 100*l.* lent, until the money is returned. When this is not the case, and when the money paid for the loan depends upon the success of an undertaking, or any casualty not connected with the duration of life, it is called a *dividend;* when the money and its interest are to be returned by yearly instalments, and paid off in a certain fixed number of years, it is called an *annuity certain;* but when the payment is to depend upon the life of any person or persons, it is called a *life annuity.* [ANNUITY.] But by whatever name the proceeds of money may be called, the rules of calculation are the same in every case but that of a life contingency.

A simple rule for converting shillings, pence, and farthings into the decimal of a pound, alluded to in the article ANNUITIES, might be made of such frequent use in calculations connected with interest, that we begin with it. The rule is founded upon the circumstance of one farthing being very little more than the thousandth part of a pound.

To convert any number of shillings, pence, and farthings to the decimal of 1*l.*, as far as three places.

RULE.—Allow 100 for every two shillings, and 50 for the odd shilling, if there be one, and a unit for every farthing in the pence and farthings, adding 1 if the pence and farthings be sixpence or upwards. Then make three decimal places of the result. Thus, 1*s.* 7¾*d.* give 50 and 31 and 1, or 82, which, converted into a decimal of three places, is ·082, or 1*s.* 7¾*d.* is ·082*l.*: the truth lies between ·0822 and ·0823. Again, 17*s.* 4½*d.* give 800 and 50 and 18, or ·868, so that 17*s.* 4½*d.* is ·868*l.* very nearly.

To convert any decimal of a pound of three places into shillings, pence, and farthings.

RULE.—Take away the decimal point, and make a whole number of the three places: for every 100 of this whole number allow two shillings, and another shilling to the remaining 50, if so much remain. Let every unit of the remainder be one farthing, but strike off one if the remaining number exceed 24. Thus, ·973*l.* gives 18*s.* and 1*s.* and 23 farthings, or 19*s.* 5¾*d.*; but ·147*l.* gives 2*s.* and 46 farthings, or 2*s.* 11½*d.* The following are examples of both rules:—

6¾*d.* is ·028*l.*	16*s.* 0½*d.* is ·802*l.*
3*s.* 2*d.* is ·158*l.*	17*s.* 11*d.* is ·895*l.*
4*s.* 9¼*d.* is ·238*l.*	19*s.* 10½*d.* is ·993*l.*

This rule may be completed, so as to give any number of places, as follows:—For the fourth and fifth places of decimals, allow 4 for every farthing above the last sixpence, with a unit additional for every six farthings. Thus, for 2*s.* 5½*d.*, the first three places being ·122, the fourth and fifth places are found by 22 × 4 + 3, or 91. For the sixth and all following places, take the number of farthings above the last three halfpence for a numerator, 6 for a denominator, and form the figures of the corresponding decimal fraction. In the above instance we have ⅔, or ·6666 ...., whence 2*s.* 5½*d.* is ·122916666*l.* ....

Interest is usually reckoned by the sum paid yearly for each 100*l.*; thus, 4 *per centum*, abbreviated into 4 *per cent.*, means that 4*l.* is paid yearly for 100*l.*, or that $\frac{1}{25}$th of the whole sum is paid yearly for its use. In some cases, as in the dividend of a bankrupt's estate, a part is compared with the whole by stating how much of each pound is paid. The preceding rule gives the means of reducing one to the other instantaneously: thus, since 4*s.* 9¼*d.* is ·238*l.*, a bankrupt who pays the former sum per pound, or ·238*l.* for 1*l.*, pays 23·8*l.* for each 100*l.*, or 23⅘ per cent. Similarly, 37⅕ per cent., or 37·2*l.* for 100*l.*, is ·372*l.* for 1*l.*, or 7*s.* 5½*d.* in the pound.

Interest is called *simple* when it is paid as soon as due, or when, if deferred, interest is not charged upon interest. But when the latter charge is made, the interest is called *compound.* In simple interest it makes no difference whether it be payable yearly or at shorter terms; but this is not the case in compound interest. The sum lent is called the *principal;* and the principal, together with the interest, the *amount;* also, the principal is called the *present value* of the amount.

A common question of simple interest requires merely the process of taking a given fractional part of a sum of money, and need not be explained at length in a work of reference. One example, however, will serve to show the facilities which the preceding rule affords.

What is the interest upon 697*l.* 13*s.* 4½*d.*, at 4½ per cent., for 7¾ years?

To find this, we must take the hundredth part of the sum 4½ times for one year's interest, which we must then repeat 7¾ times.

£697 13*s.* 4½*d.* is £697·668

£697·668	
4½	
2790·672	
348·834	
100)3139·506	
31·39506	or 31·39506
7¾	8
219·76542	251·16048
15·69753	7·84877
7·84877	243·31171
243·31172	

Answer £243·312 or £243 6*s.* 3*d.*

When interest is to be taken for a number of days, a person who is often required to perform the operation will provide himself with a set of tables, several of which are published. Those who do not often meet with the operation must take such a fraction of a year's interest as the number of days in the question is of a year. The following rule will facilitate the introduction of the arithmetical rule of practice:—

RULE.—Whenever the portion of an amount per annum is to be taken corresponding to a number of days, calculate as if the year had only 360 days, and from the result subtract its 72nd part, or one farthing in 1*s.* 6*d.*, or 3½*d.* on each guinea. This falls short of the truth by about 1*d.* in 20*l.* Thus, suppose the yearly interest is 283*l.* 17*s.* 4*d.*, and that for 254 days is required—

		283·866
180	½	141·933
60	⅓	47·311
12	⅕	9·462
2	⅙	1·577
		8)200·283
		9) 25·035
		2·782
		200·283
		197·501

Answer, 197*l.* 10*s.*;—or, adding 1*d.* for each 20*l.*, about 197*l.* 10*s.* 10*d.*, which is within one halfpenny of the truth.

It is sometimes necessary to express the interest by the day, in which the following rules will be convenient:—

To turn a given amount per day into the corresponding amount per year, to the number of pence per day add its half, and take as many pounds as there are now pence. This is the amount in 360 days, and five days' allowance added gives the result.

To find out how much a sum per annum yields per day, subtract one-third from the pounds, and take as many pence as there are in the result. The answer is the preceding result diminished by one farthing in 1*s.* 6*d.*, or its 72nd part.

Thus, 3¾*d.* per day, or 3·75 pence, gives 3·75 + 1·875, or 5·625 per 360 days, which is 5*l.* 12*s.* 6*d.* To this add five times 3¾*d.*, or 1*s.* 6¾*d.*, which gives 5*l.* 14*s.* 0¾*d.* per annum.

Again, 26*l.* 14*s.* 7*d.* per annum, or (nearly enough) 26·7*l.*, gives 26·7—8·9 pence per day nearly; that is, 1*s.* 5¾*d.* Diminish this by one farthing, and 1*s.* 5½*d.* is the answer within a farthing.

All persons who attempt for the first time to use decimal fractions in money computations imagine that they gain nothing; but a little practice soon convinces them of the contrary.

We now proceed to the subject of compound interest, which cannot be satisfactorily treated without algebra. Let r be the interest of 1*l.* for one year, or $100\,r$ the rate per cent. As follows:—

At 2¼ per cent. $r = {\cdot}0225$	At 4 per cent. $r = {\cdot}04$
At 3½ per cent. $r = {\cdot}035$	At 5⅛ per cent. $r = {\cdot}05125$.

It is not usual in treating of compound interest to separate that part of the amount which is interest from the whole. We shall, therefore, speak only of principal and amount, or, when the latter is the given sum, of present value and deferred principal. Hence, $1 + r$ is the amount of 1*l.* in one year, $2 + 2r$ that of 2*l.* in one year, and, generally, a sum which is a pounds at the beginning of any one year becomes $a(1 + r)$ pounds at the end.

Consequently, the amounts of 1*l.* at the end of one, two, three, &c., years, are $1 + r$, $(1 + r)^2$, $(1 + r)^3$, &c., pounds; and 1*l.* at the end of n years becomes $(1 + r)^n$ pounds. If, then, £a becomes £A in n years, at r per pound, we have

$$A = a\,(1 + r)^n \qquad a = \frac{A}{(1 + r)^n}$$

$$r = \sqrt[n]{\frac{A}{a}} - 1 \qquad n = \frac{\log A - \log a}{\log (1 + r)}$$

from one of which forms of the equation, either of the four, A, a, r, or n, can be found, when the other three are known.

From the second form it appears that the fraction of 1*l*., which will in a year amount to a pound, is 1 divided by $1 + r$. Let this be called v; we have then

$$v = \frac{1}{1+r} \qquad r = \frac{1-v}{v}$$

Hence it is easily seen, that according as a pound is to be the amount at the end of one, two, three, &c., years, the principal now necessary to produce that amount is v, v^2, v^3, &c., or v^n expresses "the present value of 1*l*. to be received at the end of n years." Here are no less than *fifteen* words necessary to express a fundamental result; and when we speak of $(1+r)^n$ it must be as "the amount of 1*l*. in n years." To shorten these phrases, the former might be advantageously called the nth present value, and the latter the nth amount.

The sum which yields 1*l*. every year is called the value of a perpetuity of one pound, or simply the *perpetuity* of 1*l*. If it be P, we have

$$\text{P}r = 1, \text{P} = \frac{1}{r}, r = \frac{1}{\text{P}}, \text{P} = \frac{v}{1-v}, v = \frac{\text{P}}{1+\text{P}}.$$

The reader will find an arithmetical account of ANNUITIES under that word; we now proceed to the algebraical formulæ connected with them. An annuity, and also a perpetuity, is always said to be created a year before any payment is made: thus an immediate grant of an annuity payable yearly implies that the first payment is made a year hence; and similarly of a perpetuity. But in cases where we have to speak of an annuity or perpetuity, of which one payment is to be made now, we propose to call them an annuity due, and a perpetuity due. Again, an annuity or perpetuity deferred for, say 10 years, makes its first payment in 11 years: but a perpetuity due in 10 years, makes the first payment at the end of 10 years. An annuity of 20 years makes 20 payments; an annuity due of 20 years makes 21 payments. Let all annuities mentioned be of 1*l*., unless otherwise specified.

The present value of an annuity for n years is evidently

$$v + v^2 + v^3 + \ldots + v^{n-1} + v^n$$

for v in one year becomes 1*l*., and provides for the first payment; v^2 for the second, and so on. The preceding is equivalent to

$$\frac{v - v^{n+1}}{1-v} \quad \text{or} \quad \frac{1-v^n}{r} \quad \text{or} \quad \frac{(1+r)^n - 1}{r(1+r)^n}$$

Similarly the present value of an annuity due for n years is 1*l*. more than the preceding, or

$$\frac{1 - v^{n+1}}{1-v} \quad \text{or} \quad \frac{1+r-v^n}{r} \quad \text{or} \quad \frac{(1+r)^{n+1} - 1}{r(1+r)^n}$$

TABLE I.

THE PRESENT VALUE OF £1, DUE AT THE END OF ANY NUMBER OF YEARS.

Yrs.	2½ per Ct.	3 per Ct.	3½ per Ct.	4 per Ct.	4½ per Ct.	5 per Ct.	6 per Ct.
1	·97561	·97087	.96618	·96154	·95694	·95238	·94340
2	·95181	·94260	·93351	·92456	·91573	·90703	·89000
3	·92860	·91514	·90194	·88900	·87630	·86384	·83962
4	·90595	·88849	·87144	·85480	·83856	·82270	·79209
5	·88385	·86261	·84197	·82193	·80245	·78353	·74726
6	·86230	·83748	·81350	·79031	·76790	·74622	·70496
7	·84127	·81309	·78599	·75992	·73483	·71068	·66506
8	·82075	·78941	·75941	·73069	·70319	·67684	·62741
9	·80073	·76642	·73373	·70259	·67290	·64461	·59190
10	·78120	·74409	·70892	·67556	·64393	·61391	·55839
11	·76214	·72242	·68495	·64958	·61620	·58468	·52679
12	·74356	·70138	·66178	·62460	·58966	·55684	·49697
13	·72542	·68095	·63940	·60057	·56427	·53032	·46884
14	·70773	·66112	·61778	·57748	·53997	·50507	·44230
15	·69047	·64186	·59689	·55526	·51672	·48102	·41727
16	·67362	·62317	·57671	·53391	·49447	·45811	·39365
17	·65720	·60502	·55720	·51337	47318	·43630	·37136
18	·64117	·58739	·53836	·49363	·45280	·41552	·35034
19	·62553	·57029	·52016	·47464	·43330	·39573	·33051
20	·61027	·55368	·50257	·45639	·41464	·37689	·31180
21	·59539	·53755	·48557	·43883	·39679	·35894	·29416
22	·58086	·52189	·46915	·42196	·37970	·34185	·27751
23	·56670	·50669	·45329	·40573	·36335	·32557	·26180
24	·55288	·49193	·43796	·39012	·34770	·31007	·24698
25	·53939	·47761	·42315	·37512	·33273	·29530	·23300
26	·52623	·46369	·40884	·36069	·31840	·28124	·21981
27	·51340	·45019	·39501	·34682	·30469	·26785	·20737
28	·50088	·43708	·38165	·33348	·29157	·25509	·19563
29	·48866	·42435	·36875	·32065	·27902	·24295	·18456
30	·47674	·41199	·35628	·30832	·26700	·23138	·17411
31	·46511	·39999	·34423	·29646	·25550	·22036	·16425
32	·45377	·38834	·33259	·28506	·24450	·20987	·15496
33	·44270	·37703	·32134	·27409	·23397	·19987	·14619
34	·43191	·36604	·31048	·26355	·22390	·19035	·13791
35	·42137	·35538	·29998	·25342	·21425	·18129	·13011
36	·41109	·34503	·28983	·24367	·20503	·17266	·12274
37	·40107	·33498	·28003	·23430	·19620	·16444	·11580
38	·39128	·32523	·27056	·22529	·18775	·15661	·10924
39	·38174	·31575	·26141	·21662	·17967	·14915	·10306
40	·37243	·30656	·25257	·20829	·17193	·14205	·09722
41	·36335	·29763	·24403	·20028	·16453	·13528	·09172
42	·35448	·28896	·23578	·19257	·15744	·12884	·08653
43	·34584	·28054	·22781	·18517	·15066	·12270	·08163
44	·33740	·27237	·22010	·17805	·14417	·11686	·07701
45	·32917	·26444	·21266	·17120	·13796	·11130	·07265
46	·32115	·25674	·20547	·16461	·13202	·10600	·06854
47	·31331	·24926	·19852	·15828	·12634	·10095	·06466
48	·30567	·24200	·19181	·15219	·12090	·09614	·06100
49	·29822	·23495	·18532	·14634	·11569	·09156	·05755
50	·29094	·22811	·17905	·14071	·11071	·08720	·05429
55	·25715	·19677	·15076	·11566	·08884	·06833	·04057
60	·22728	·16973	·12693	·09506	·07129	·05354	·03031
65	·20089	·14641	·10688	·07813	·05721	·04195	·02265
70	·17755	·12630	·08999	·06422	·04590	·03287	·01693
75	·15693	·10895	·07577	·05278	·03684	·02575	·01265
80	·13870	·09398	·06379	·04338	·02956	·02018	·00945
85	·12259	·08107	·05371	·03566	·02372	·01581	·00706
90	·10836	·06993	.04522	·02931	·01903	·01239	·00528
95	·09577	·06032	.03808	·02409	·01527	·00971	·00394
100	·08465	·05203	.03206	·01980	·01226	·00760	·00295

TABLE II.

THE PRESENT VALUE OF £1 PER ANNUM FOR ANY NUMBER OF YEARS.

Yrs.	2½ per Ct.	3 per Ct.	3½ per Ct.	4 per Ct.	4½ per Ct.	5 per Ct.	6 per Ct.
1	·97561	·97087	·96618	·96154	·95694	·95238	·94340
2	1·92742	1·91347	1·89969	1·88609	1·87267	1·85941	1·83339
3	2·85602	2·82861	2·80164	2·77509	2·74896	2·72325	2·67301
4	3·76197	3·71710	3·67308	3·62990	3·58753	3·54595	3·46511
5	4·64583	4·57971	4·51505	4·45182	4·38998	4·32948	4·21236
6	5·50813	5·41719	5·32855	5·24214	5·15787	5·07569	4·91732
7	6·34939	6·23028	6·11454	6·00205	5·89270	5·78637	5·58238
8	7·17014	7·01969	6·87396	6·73274	6·59589	6·46321	6·20979
9	7·97087	7·78611	7·60769	7·43533	7·26879	7·10782	6·80169
10	8·75206	8·53020	8·31661	8·11090	7·91272	7·72173	7·36009
11	9·51421	9·25262	9·00155	8·76048	8·52892	8·30641	7·88687
12	10·25776	9·95400	9·66333	9·38507	9·11858	8·86325	8·38384
13	10·98318	10·63496	10·30274	9·98565	9·68285	9·39357	8·85268
14	11·69091	11·29607	10·92052	10·56312	10·22283	9·89864	9·29498
15	12·38138	11·93794	11·51741	11·11839	10·73955	10·37966	9·71225
16	13·05500	12·56110	12·09412	11·65230	11·23402	10·83777	10·10590
17	13·71220	13·16612	12·65132	12·16567	11·70719	11·27407	10·47726
18	14·35336	13·75351	13·18968	12·65930	12·15999	11·68959	10·82760
19	14·97889	14·32380	13·70984	13·13394	12·59329	12·08532	11·15812
20	15·58916	14·87747	14·21240	13·59033	13·00794	12·46221	11·46992
21	16·18455	15·41502	14·69797	14·02916	13·40472	12·82115	11·76408
22	16·76541	15·93692	15·16712	14·45112	13·78442	13·16300	12·04158
23	17·33211	16·44361	15·62041	14·85684	14·14777	13·48857	12·30338
24	17·88499	16·93554	16·05837	15·24696	14·49548	13·79864	12·55036
25	18·42438	17·41315	16·48151	15·62208	14·82821	14·09394	12·78336
26	18·95061	17·87684	16·89035	15·98277	15·14661	14·37519	13·00317
27	19·46401	18·3270	17·28536	16·32959	15·45130	14·64303	13·21053
28	19·96489	18·76411	17·66702	16·66306	15·74287	14·89813	13·40616
29	20·45355	19·18845	18·03577	16·98371	16·02189	15·14107	13·59072
30	20·93029	19·60044	18·39205	17·29203	16·28889	15·37245	13·76483
31	21·39541	20·00043	18·73628	17·58849	16·54439	15·59281	13·92909
32	21·84918	20·38877	19·06887	17·87355	16·78889	15·80268	14·08404
33	22·29188	20·76579	19·39021	18·14765	17·02286	16·00255	14·23023
34	22·72379	21·13184	19·70068	18·41120	17·24676	16·19290	14·36814
35	23·14516	21·48722	20·00066	18·66461	17·46101	16·37419	14·49825
36	23·55625	21·83225	20·29049	18·90828	17·66604	16·54685	14·62099
37	23·95732	22·16724	20·57053	19·14258	17·86224	16·71129	14·73678
38	24·34860	22·49246	20·84109	19·36786	18·04999	16·86789	14·84602
39	24·73034	22·80822	21·10250	19·58448	18·22966	17·01704	14·94907
40	25·10278	23·11477	21·35507	19·79277	18·40158	17·15909	15·04630
41	25·46612	23·41240	21·59910	19·99305	18·56611	17·29437	15·13802
42	25·82061	23·70136	21·83488	20·18563	18·72355	17·42321	15·22454
43	26·16645	23·98190	22·06269	20·37079	18·87421	17·54591	15·30617
44	26·50385	24·25427	22·28279	20·54884	19·01838	17·66277	15·38318
45	26·83302	24·51871	22·49545	20·72004	19·15636	17·77407	15·45583
46	27·15417	24·77545	22·70092	20·88465	19·28837	17·88007	15·52437
47	27·46748	25·02471	22·89944	21·04294	19·41471	17·98102	15·58903
48	27·77315	25·26671	23·09124	21·19513	19·53561	18·07716	15·65003
49	28·07137	25·50166	23·27656	21·34147	19·65130	18·16872	15·70757
50	28·36231	25·72976	23·45562	21·48218	19·76201	18·25593	15·76186
55	29·71398	26·77443	24·26405	22·10861	20·24802	18·63447	15·99054
60	30·90866	27·67556	24·94473	22·62349	20·63802	18·92929	16·16143
65	31·96458	28·45289	25·51785	23·04668	20·95098	19·16107	16·28912
70	32·89786	29·12342	26·00040	23·39451	21·20211	19·34268	16·38454
75	33·72274	29·70183	26·40669	23·68041	21·40363	19·48497	16·45585
80	34·45182	30·20076	26·74878	23·91539	21·56534	19·59646	16·50913
85	35·09621	30·63115	27·03680	24·10853	21·69511	19·68382	16·54895
90	35·66577	31·00241	27·27932	24·26728	21·79924	19·75226	16·57870
95	36·16917	31·32266	27·48350	24·39776	21·88280	19·80589	16·60093
100	36·61411	31·59891	27·65543	24·50500	21·94985	19·84791	16·61755

An annuity of n years deferred for k years is now worth

$$v^{k+1}+v^{k+2}+\ldots\ldots+v^{k+n}$$

$$\text{or } v^k\frac{v-v^{n+1}}{1-v} \quad \text{or} \quad \frac{v^k-v^{n+k}}{r} \quad \text{or} \quad \frac{(1+r)^n-1}{r(1+r)^{n+k}}$$

A perpetuity deferred for k years is worth $\frac{v^k}{r}$ or $v^k P$; but a perpetuity due in k years is the same as a perpetuity deferred for $k-1$ years, and $k-1$ must be written for k in the preceding; giving $v^{k-1}P$.

If the proceeds of an annuity of n years be put out to interest as fast as they become due, then at the instant after the last payment is made the first payment will have improved for $n-1$ years, the second for $n-2$ years, &c., and the last payment will have made nothing: whence the whole amount of the annuity at the moment of expiration is

$$(1+r)^{n-1}+(1+r)^{n-2}+\ \ldots\ldots\ +(1+r)+1$$

$$\text{which is } \frac{(1+r)^n-1}{r} \quad \text{or} \quad \frac{1-v^n}{rv^n}$$

The annuity of n years, which 1*l.* will buy, makes at each payment $r \div (1-v^n)$; and so on: that is, the following are methods of restoring 1*l.* now lent:—

1. By annuity for n years . . . . of $\frac{r}{1-v^n}$
2. By annuity for n years, deferred k years, of $\frac{r}{v^k-v^{n+k}}$
3. By perpetuity . . . . . . of r
4. By perpetuity deferred for k years . . of $\frac{r}{v^k}$

And 1*l.* due at the end of n years, may be paid by an n years annuity of $rv^n \div (1-v^n)$, or by an annuity due of $rv^n \div (1+r-v^n)$.

It is hardly necessary to say, that an annuity, &c., of £s is to be found by multiplying the annuity, &c., of 1*l.* by s.

An annuity of n years, which gives 1*l.* at the first payment, 2*l.* at the second payment, &c., and £n at the nth and last payment, is worth

$$\frac{v+nv^{n+2}-(n+1)v^{n+1}}{(1-v)^2}$$

and when the numerator and denominator change places, we have the fraction of 1*l.*, which must be paid at the end of the first year, in order to repay 1*l.* now lent, by uniformly increasing instalments in n years.

An annuity of n years, which gives £n at the first payment, £$(n-1)$

TABLE III.

THE ANNUITY WHICH £1 WILL PURCHASE FOR ANY NUMBER OF YEARS.

Yrs.	2½ per Ct.	3 per Ct.	3½ per Ct.	4 per Ct.	4½ per Ct.	5 per Ct.	6 per Ct.
1	1·02500	1·03000	1·03500	1·04000	1·04500	1·05000	1·06000
2	·51883	·52261	·52640	·53020	·53400	·53780	·54544
3	·35014	·35353	·35693	·36035	·36377	·36721	·37411
4	·26582	·26903	·27225	·27549	·27874	·28201	·28859
5	·21525	·21835	·22148	·22463	·22779	·23097	·23740
6	·18155	·18460	·18767	·19076	·19388	·19702	·20336
7	·15750	·16051	·16354	·16661	·16970	·17282	·17914
8	·13947	·14246	·14548	·14853	·15161	·15472	·16104
9	·12546	·12843	·13145	·13449	·13757	·14069	·14702
10	·11426	·11723	·12024	·12329	·12638	·12950	·13587
11	·10511	·10808	·11109	·11415	·11725	·12039	·12679
12	·09749	·10046	·10348	·10655	·10967	·11283	·11928
13	·09105	·09403	·09706	·10014	·10328	·10646	·11296
14	·08554	·08853	·09157	·09467	·09782	·10102	·10758
15	·08077	·08377	·08683	·08994	·09311	·09634	·10296
16	·07660	·07961	·08268	·08582	·08902	·09227	·09895
17	·07293	·07595	·07904	·08220	·08542	·08870	·09544
18	·06967	·07271	·07582	·07899	·08224	·08555	·09236
19	·06676	·06981	·07294	·07614	·07941	·08275	·08962
20	·06415	·06722	·07036	·07358	·07688	·08024	·08718
21	·06179	·06487	·06804	·07128	·07460	·07800	·08500
22	·05965	·06275	·06593	·06920	·07255	·07597	·08305
23	·05770	·06081	·06402	·06731	·07068	·07414	·08128
24	·05591	·05905	·06227	·06559	·06899	·07247	·07968
25	·05428	·05743	·06067	·06401	·06744	·07095	·07823
26	·05277	·05594	·05921	·06257	·06602	·06956	·07690
27	·05138	·05456	·05785	·06124	·06472	·06829	·07570
28	·05009	·05329	·05660	·06001	·06352	·06712	·07459
29	·04889	·05211	·05545	·05888	·06241	·06605	·07358
30	·04778	·05102	·05437	·05783	·06139	·06505	·07265
31	·04674	·05000	·05337	·05686	·06044	·06413	·07179
32	·04577	·04905	·05244	·05595	·05956	·06328	·07100
33	·04486	·04816	·05157	·05510	·05874	·06249	·07027
34	·04401	·04732	·05076	·05431	·05798	·06176	·06960
35	·04321	·04654	·05000	·05358	·05727	·06107	·06897
36	·04245	·04580	·04928	·05289	·05661	·06043	·06839
37	·04174	·04511	·04861	·05224	·05598	·05984	·06786
38	·04107	·04446	·04798	·05163	·05540	·05928	·06736
39	·04044	·04384	·04739	·05106	·05486	·05876	·06689
40	·03984	·04326	·04683	·05052	·05434	·05828	·06646
41	·03927	·04271	·04630	·05002	·05386	·05782	·06606
42	·03873	·04219	·05580	·04954	·05341	·05739	·06568
43	·03822	·04170	·04533	·04909	·05298	·05699	·06533
44	·03773	·04123	·04488	·04866	·05258	·05662	·06501
45	·03727	·04079	·04445	·04826	·05220	·05626	·06470
46	·03683	·04036	·04405	·04788	·05184	·05593	·06441
47	·03641	·03996	·04367	·04752	·05151	·05561	·06415
48	·03601	·03958	·04331	·04718	·05119	·05532	·06390
49	·03562	·03921	·04296	·04686	·05089	·05504	·06366
50	·03526	·03887	·04263	·04655	·05060	·05478	·06344
55	·03365	·03735	·04121	·04523	·04939	·05367	·06254
60	·03235	·03613	·04009	·04420	·04845	·05283	·06188
65	·03128	·03515	·03919	·04339	·04773	·05219	·06139
70	·03040	·03434	·03846	·04275	·04717	·05170	·06103
75	·02965	·03367	·03787	·04223	·04672	·05132	·06077
80	·02903	·03311	·03738	·04181	·04637	·05103	·06057
85	·02849	·03265	·03699	·04148	·04609	·05080	·06043
90	·02804	·03226	·03668	·04121	·04587	·05063	·06032
95	·02765	·03193	·03639	·04099	·04570	·05049	·06024
100	·02731	·03165	·03616	·04081	·04556	·05038	·06018

TABLE IV.

THE AMOUNT OF £1 IN ANY NUMBER OF YEARS.

Yrs.	2½ per Ct.	3 per Ct.	3½ per Ct.	4 per Ct.	4½ per Ct.	5 per Ct.	6 per Ct.
1	1·02500	1·03000	1·03500	1·04000	1·04500	1·05000	1·06000
2	1·05063	1·06090	1·07123	1·08160	1·09203	1·10250	1·12360
3	1·07689	1·09273	1·10872	1·12486	1·14117	1·15763	1·19102
4	1·10381	1·12551	1·14752	1·16986	1·19252	1·21551	1·26248
5	1·13141	1·15927	1·18769	1·21665	1·24618	1·27628	1·33823
6	1·15969	1·19405	1·22926	1·26532	1·30226	1·34010	1·41852
7	1·18869	1·22987	1·27228	1·31593	1·36086	1·40710	1·50363
8	1·21840	1·26677	1·31681	1·36857	1·42210	1·47746	1·59385
9	1·24886	1·30477	1·36290	1·42331	1·48610	1.55133	1·68948
10	1·28008	1·34392	1·41060	1·48024	1·55297	1·62889	1·79085
11	1·31209	1·38423	1·45997	1·53945	1·62285	1·71034	1·89830
12	1·34489	1·42576	1·51107	1·60103	1·69588	1·79586	2·01220
13	1·37851	1·46853	1·56396	1·66507	1·77220	1·88565	2·13293
14	1·41297	1·51259	1·61869	1·73168	1·85194	1·97993	2·26090
15	1·44830	1·55797	1·67535	1·80094	1·93528	2·07893	2·39656
16	1·48451	1·60471	1·73399	1·87298	2·02237	2·18287	2·54035
17	1·52162	1·65285	1·79468	1·94790	2·11338	2·29202	2·69277
18	1·55966	1·70243	1·85749	2·02582	2·20848	2·40662	2·85434
19	1·59865	1·75351	1·92250	2·10685	2·30786	2·52695	3·02560
20	1·63862	1·80611	1·98979	2·19112	2·41171	2·65330	3·20714
21	1·67958	1·86029	2·05943	2·27877	2·52024	2·78596	3·39956
22	1·72157	1·91610	2·13151	2·36992	2·63365	2·92526	3·60354
23	1·76461	1·97359	2·20611	2·46472	2·75217	3·07152	3·81975
24	1·80873	2·03279	2·28333	2·56330	2·87601	3·22510	4·04893
25	1·85394	2·09378	2·36324	2·66584	3·00543	3·38635	4·29187
26	1·90029	2·15659	2·44596	2·77247	3·14068	3·55567	4·54938
27	1·94780	2·22129	2·53157	2·88337	3·28201	3·73346	4·82235
28	1·99650	2·28793	2·62017	2·99870	3·42970	3·92013	5·11169
29	2·04641	2·35657	2·71188	3·11865	3·58404	4·11614	5.41839
30	2·09757	2·42726	2·80679	3·24340	3·74532	4·32194	5·74349
31	2·15001	2·50008	2·90503	3·37313	3·91386	4·53804	6·08810
32	2·20376	2·57508	3·00671	3·50806	4·08998	4·76494	6·45339
33	2·25885	2·65234	3·11194	3·64838	4·27403	5·00319	6·84059
34	2·31532	2·73191	3·22086	3·79432	4·46636	5·25335	7·25103
35	2·37321	2·81386	3·33359	3·94609	4·66735	5·51602	7·68609
36	2·43254	2·89828	3·45027	4·10393	4·87738	5·79182	8·14725
37	2·49335	2·98523	3·57103	4·26809	5·09686	6·08141	8·63609
38	2·55568	3·07478	3·69601	4·43881	5·32622	6·38548	9·15425
39	2·61957	3·16703	3·82537	4·61637	5·56590	6·70475	9·70351
40	2·68506	3·26204	3·95926	4·80102	5·81636	7·03999	10·28572
41	2·75219	3·35990	4·09783	4·99306	6·07810	7·39199	10·90286
42	2·82100	3·46070	4·24126	5·19278	6·35162	7·76159	11·55703
43	2·89152	3·56452	4·38970	5·40050	6·63744	8·14967	12·25045
44	2·96381	3·67145	4·54334	5·61652	6·93612	8·55715	12·98548
45	3·03790	3·78160	4·70236	5·84118	7·24825	8·98501	13·76461
46	3·11385	3·89504	4·86694	6·07482	7·57442	9·43426	14·59049
47	3·19170	4·01190	5·03728	6·31782	7·91527	9·90597	15·46592
48	3·27149	4·13225	5·21359	6·57053	8·27146	10·40127	16·39387
49	3·35328	4·25622	5·39606	6·83335	8·64367	10·92133	17·37750
50	3·43711	4·38391	5·58493	7·10668	9·03264	11·46740	18·42015
55	3·88877	5·08215	6·63314	8·64637	11·25631	14·63563	24·65032
60	4·39979	5·89160	7·87809	10·51963	14·02741	18·67919	32·98769
65	4·97796	6·82998	9·35670	12·79874	17·48070	23·83990	44·14497
70	5·63210	7·91782	11·11283	15·57162	21·78414	30·42643	59·07593
75	6·37221	9·17893	13·19855	18·94525	27·14700	38·83269	79·05692
80	7·20957	10·64089	15·67574	23·04980	33·83010	49·56144	105·7960
85	8·15666	12·33571	18·61786	28·04360	42·15846	63·25435	141·5789
90	9·22886	14·30047	22·11218	34·11933	52·53711	80·73037	189·4645
95	10·44160	16·57816	26·26233	41·51139	65·47079	103·0347	253·5463
100	11·81327	19·21863	31·19141	50·50495	81·58852	131·5013	339·3021

TABLE V,

THE AMOUNT OF £1 PER ANNUM IN ANY NUMBER OF YEARS.

Years.	2½ per Cent.	3 per Cent.	3½ per Cent.	4 per Cent.	4½ per Cent.	5 per Cent.	6 per Cent.
1	1·00000	1·00000	1·00000	1·00000	1·00000	1·00000	1·00000
2	2·02500	2·03000	2·03500	2·04000	2·04500	2·05000	2·06000
3	3·07563	3·09090	3·10623	3·12160	3·13703	3·15250	3·18360
4	4·15252	4·18363	4·21494	4·24646	4·27819	4·31013	4·37462
5	5·25633	5·30914	5·36247	5·41632	5·47071	5·52563	5·63709
6	6·38774	6·46841	6·55015	6·63298	6·71689	6·80191	6·97532
7	7·64743	7·66246	7·77941	7·89829	8·01915	8·14201	8·39384
8	8·73612	8·89234	9·05169	9·21423	9·38001	9·54911	9·89747
9	9·95452	10 15911	10·36850	10·58280	10·80211	11·02656	11·49132
10	11·20338	11·46388	11·73139	12·00611	12·28821	12·57789	13·18079
11	12·48347	12·80780	13·14199	13·48635	13·84118	14·20679	14·97164
12	13·79555	14·19203	14·60196	15·02581	15·46403	15·91713	16·86994
13	15·14044	15·61779	16·11303	16.62684	17·15991	17·71298	18·88214
14	16·51895	17·08632	17·67699	18·29191	18·93211	19·59863	21·01507
15	17·93193	18·59891	19·29568	20·02359	20·78405	21·57856	23·27597
16	19·38022	20·15688	20·97103	21·82453	22·71934	23·65749	25·67253
17	20·86473	21·76159	22·70502	23·69751	24·74171	25·84037	28·21288
18	22·38635	23·41444	24·49969	25·64541	26·85508	28·13238	30·90565
19	23·94601	25·11687	26 35718	27 67123	29·06356	30·53900	33·75999
20	25·54466	26·87037	28·27968	29·77808	31·37142	33·06595	36·78559
21	27·18327	28·67649	30·26947	31·96920	33·78314	35·71925	39·99273
22	28 86286	30·53678	32·32890	34·24797	36·30338	38·50521	43·39229
23	30·58443	32·45288	34·46041	36·61789	38·93703	41·43048	46·99583
24	32 34904	34·42647	36·66653	39·08260	41·68920	44·50200	50·81558
25	34·15776	36·45926	38·94986	41·64591	44·56521	47·72710	54·86451
26	36·01171	38·55304	41·31310	44·31174	47·57064	51·11345	59·15638
27	37·91200	40·70963	43·75906	47·08421	50·71132	54·66913	63·70577
28	39·85980	42·93092	46·29063	49·96758	53·99333	58·40258	68·52811
29	41·85630	45·21885	48·91080	52·96629	57·42303	62·32271	73·63980
30	43·90270	47·57542	51·62268	56·08494	61·00707	66·43885	79·05819
31	46·00027	50·00268	54·42947	59·32834	64·75239	70·76079	84·80168
32	48·15028	52·50276	57·33450	62·70147	68·66625	75·29883	90·88978
33	50·35403	55·07784	60·34121	66·20953	72·75623	80·06377	97·34316
34	52·61289	57·73018	63·45315	69·85791	77·03026	85·06696	104·18375
35	54·92821	60·46208	66·67401	73·65222	81·49662	90·32031	111·43478
36	57·30141	63·27594	70·00760	77·59831	86·16397	95·83632	119·12087
37	59·73395	66·17422	73·45787	81·70225	91·04134	101·62814	127·26812
38	62·22730	69·15945	77·02889	85·97034	96·13820	107·70955	135·90421
39	64·78298	72·23423	80·72491	90·40915	101·46442	110·49502	145·05846
40	67·40255	75·40126	84·55028	95·02552	107·03032	120·79977	154·76197
41	70·08762	78·66330	88 50954	99·82654	112·84669	127·83976	165·04768
42	72·83981	82·02320	92·60737	104·81960	118·92479	135·23175	175·95054
43	75·66080	85·48389	96·84863	110·01238	125·27640	142·99334	187·50758
44	78·55232	89·04841	101·23833	115·41288	131·91384	151·14301	199·75803
45	81·51613	92·71986	105·78167	121·02939	138·84997	159·70016	212·74351
46	84·55403	96·50146	110·48403	126·87057	146·09821	168 68516	226·50812
47	87·66789	100·39650	115·35097	132·94539	153·67263	178·11942	241·09861
48	90·85958	104·40840	120·38826	139·26321	161·58790	198·02539	256·56453
49	94·13107	108·54065	125·60185	145·83373	169·85936	198·42666	272·95840
50	97·48435	112·79687	130·99791	152·66708	178·50303	209·34800	290·33590
55	115·55092	136·07162	160·94689	191·15917	227·91796	272·71262	394·17203
60	135·99159	163·05344	196·51688	237·99069	289·49795	353·58372	533·12818
65	159·11833	194·33276	238·76288	294·96838	366·23783	456·79801	719·08286
70	185·28411	230·59406	288·93786	364·29046	461·86968	588·52851	967 93217
75	214·88830	272·63086	348·53001	448·63137	581·04436	756·65372	1300·94868
80	248·38271	321·36302	419·30679	551·24498	729·55770	971·22882	1746·59989
85	286·27857	377·85695	503·86720	676·09012	914·63234	1245·08707	2342·98174
90	329·15425	443·34890	603·20503	827·98333	1145·26901	1594·60730	3141·07519
95	377·66415	519·27203	721·78082	1012·78465	1432·68426	2040·69353	4209·10425
100	432·54865	607·28773	862·61160	1237·62370	1790·85596	2610·02516	5638·36806

at the second payment, &c., and 1*l.* at the *n*th and last payment is worth

$$\frac{nv + v^{n+2} - (n+1)\,v^2}{(1-v)^2}$$

and, reversing numerator and denominator, we have the fraction of 1*l.*, which must be paid at the end of the first year, in order to repay 1*l.* now lent, by uniformly decreasing instalments in *n* years.

All the preceding formulæ are easy to compute by aid of logarithms, and the result of any one being given, and the rate of interest, it is easy to determine (except in the two last formulæ) the number of years necessary. But if the number of years be given, and the result, and it is the rate of interest which is unknown, an equation must be solved, the degree of which is at least as high as the number of years.

When the interest is to be paid at the expiration of a fraction of a year, it is the same thing as if a less rate of interest were paid for a greater number of years. In the preceding investigations $1 + r$ may be considered as the amount of 1*l.* at the end of a term, and *n* as the number of terms. If then quarterly interest be paid during *n* years, *r* per pound per annum gives $\frac{1}{4}r$ per pound per quarter, which continued for $4n$ quarters gives $(1 + \frac{1}{4}r)^{4n}$ for the amount.

The tables appended to this article are intended to save the trouble of calculation in ordinary cases. They extend from 2½ to 6 per cent. Higher rates are occasionally useful, but it is to be remembered that when the rate of interest is high, and the number of years not small, tables of yearly interest become sensibly incorrect when the money is really improved half-yearly or quarterly. Thus the tables at 5 per cent., with double the number of terms, will better represent the actual progress of money at 10 per cent. than the common yearly tables. The calculator who wishes to meet every case with readiness, must make himself independent of particular tables. This can be done with the common seven-decimal tables of logarithms, up to five places of decimals and 100 years: and if the logarithm of $1 + r$ be given to ten places of decimals, up to seven places and 1000 years. The following subsidiary table is therefore given, which contains the logarithms of $1 + r$, for every quarter per cent. up to 6 per cent., and to ten places of decimals. (See INTERPOLATION for a simple method of finding intermediate logarithms.)

$1+r$	Log. $(1+r)$	$1+r$	Log. $(1+r)$
1·0025	·00108 43813	1·0325	·01389 00603
1·0050	·00216 60618	1·0350	·01494 03498
1·0075	·00324 50548	1·0375	·01598 81054
1·0100	·00432 13738	1·0400	·01703 33393
1·0125	·00539 50319	1·0425	·01807 60636
1·0150	·00646 60422	1·0450	·01911 62904
1·0175	·00753 44179	1·0475	·02015 40316
1·0200	·00860 01718	1·0500	·02118 92991
1·0225	·00966 33167	1·0525	·02222 21045
1·0250	·01072 38654	1·0550	·02325 24596
1·0275	·01178 18305	1·0575	·02428 03760
1·0300	·01283 72247	1·0600	·02530 58653

By taking the first nine multiples of any one of these logarithms, a table of seven places might be formed, which should be correct in every figure. The following, for instance, is the table for 1 per cent. per quarter, or 4 per cent per annum, payable quarterly :—

1	·0043214	10	·0432137	100	0·4321374
2	·0086427	20	·0864275	200	0·8642748
3	·0129641	30	·1296412	300	1·2964121
4	·0172855	40	·1728550	400	1·7285495
5	·0216069	50	·2160687	500	2·1606869
6	·0259282	60	·2592824	600	2·5928243
7	·0302496	70	·3024962	700	3·0249617
8	·0345710	80	·3457099	800	3·4570990
9	·0388924	90	·3889236	900	3·8892364

For instance, suppose it required to find out in how many years money will increase tenfold at 4 per cent. payable quarterly : or to solve the equation $(1{\cdot}01)^{4n} = 10$.

$$\begin{array}{rl} \text{Log. } 10 = 1{\cdot}0000000 & \\ {\cdot}8642748 & \ldots\ 200 \\ \hline {\cdot}1357252 & \\ {\cdot}1296412 & \ldots\ \ 30 \\ \hline {\cdot}0060840 & \\ {\cdot}0043214 & \ldots\ \ \ 1 \\ \hline {\cdot}0017626 & \end{array}$$

Answer.—The amount of 1*l.* in 232 quarters, or 58 years, will be a little more than 10*l.*

We now describe the tables which follow :—

Table I. gives the present value of 1*l.* to be received at the end of the several years marked. Thus, in the column of 4 per cent. opposite to 15 years, we find ·55526, which is the sum that will in fifteen years, at 4 per cent., amount to 1*l.* The present value of 100*l.* similarly circumstanced, is 55·526*l.* or 55*l.* 10*s.* 6½*d.*

Table II. gives the present value of an annuity of 1*l.* Thus opposite to 20 years in the column of 5 per cent. is 12·46221, meaning that 1*l.*, to be paid at the end of every year from this time for 20 years, is now worth 12·46221*l.*, if money will make 5 per cent.

Table III. shows the annuity which 1*l.* will buy for any number of years. Thus in the column of 4 per cent., opposite to 7 years, we find ·16661. If then 100*l.*, now lent, were to be repaid by instalments in seven years, the first instalment a year hence, so as to allow compound interest at 4 per cent., then each instalment should be 16·661*l.*

Table IV. gives the amount of 1*l.* improved at compound interest during a number of years. Thus opposite to 11 years in the column of 3 per cent. is found 1·38423, meaning that 1*l.* in 11 years, at 3 per cent., amounts to 1·38423, and 100*l.* to 138·423*l.*

Table V. gives the amount of an annuity of 1*l.*, as it will be the moment after the last payment has been made, if the preceding payments have been allowed to accumulate. Thus in the column of 3½ per cent., under 27 years, we find 43·75906, so that the proceeds of an annuity of 100*l.* for 27 years, allowed to accumulate at 3½ per cent., will at the last payment have realised 4375·906*l.*

The following equations show easy means of verifying any one of these tables by another. Let I, II, III, IV, V, represent the results of the five tables for some one number of years, and rate of interest. Then

$$\mathrm{I} \times \mathrm{IV} = 1 \qquad \mathrm{I} + r \times \mathrm{II} = 1$$
$$\mathrm{II} \times \mathrm{III} = 1 \qquad \mathrm{IV} - r \times \mathrm{V} = 1$$

Interest, as payable upon a debt not discharged on the day it becomes due, is unknown to the Common Law, payment of such interest being still rather the exception than the rule. Some debts it is true carry interest by the custom of merchants or traders, being those constituted by bills, and since the statute of Anne, by promissory notes. But unless there is an express agreement to such effect between the parties, debts do not carry interest at all. This uncommercial rule of law led to the statute 3 & 4 Will. IV., c. 42, which enables a jury, if they think fit, upon all debts or sums certain, to allow interest to the creditor, at a rate not exceeding the current rate of interest, from the time when such debts or sums were payable, if payable by virtue of a written instrument at a certain time; or if payable otherwise, then from the time of a demand of payment in writing, so as such demand give notice that interest will be claimed from the date of such demand. This statute also empowers juries to give damages, in the nature of interest, in respect of the detention or appropriation of goods. By 1 & 2 Vict., c. 110, judgment-debts carry interest at the rate of 4 per cent. per annum from the time of entering up the judgment. Legacies are payable at the end of one year after a testator's death, and from the end of that year carry interest at the rate of 4 per cent. per annum; unless the testator has made special provisions in his will as to the time of payment and the rate of interest. See farther, ANNUITY, BOTTOMRY, USURY.

INTERFERENCE is a term used to express the mutual influence of two streams of light, or series of pulsations of sound, or, generally, two series of vibrations of any kind. The term is most commonly employed with reference to light.

We owe to Dr. Young the discovery of the grand principle of the interference of light, and the explanation thereby, in the most simple and satisfactory manner, of various phenomena of which no rational account had previously been given.

The principle itself, when considered merely as embodying the phenomena which belong to it, may be thus stated. When two streams of light from the same source, after traversing paths very slightly differing from each other in length, mix together, crossing at a small angle, they partially or completely neutralise each other's effect, or else strengthen each other, according to the difference of path. When the two interfering streams are of equal intensity the neutralisation is complete, and we have realised the apparent paradox of two lights producing darkness. The law which determines whether the illumination due to this joint action of the two streams is a maximum or minimum is this: When the difference of the two paths (both being supposed to be in air) is zero, or an even multiple of a certain fundamental constant, the illumination is a maximum, when an odd multiple it is a minimum. This fundamental constant depends only on the refrangibility of the light, and decreases in magnitude from the red to the violet end of the spectrum. When the incident light is white, the light of each particular degree of refrangibility of which it is composed presents the phenomena of interference independently of the light of other refrangibilities; and the precise circumstances of the interference being determined by the value of the fundamental constant belonging to the particular kind of light, a value which, as we have seen, changes from one colour to another, a maximum of illumination as regards one part of the spectrum may coincide with a minimum of illumination as regards another. Thus, alternations of colour are observed, and not merely alternations of intensity, and by the time the difference of path amounts to that belonging to the 7th or 8th maximum for mean rays, the colours are so mixed, that the result is sensibly white light of uniform intensity; though, if the interfering light is subjected to prismatic analysis, the interference may be traced up to a difference of path amounting to many thousand times the value of the fundamental constant.

The idea we attach to the fundamental constant depends on the notion we form of the nature of light. The theory of undulations alone affords a simple and clear explanation of the phenomena of interference, and is competent to meet the demands of the science of optics in its present state. According to this theory, the two streams consist of two perfectly similar series of undulations propagated in the "ether," of which in this theory the existence must be assumed. According to the general dynamical principle of the coexistence of small motions, the disturbance which one series will produce in the ether will be sensibly the same, whether that portion of ether be or be not agitated by the other series. If the lengths of path be equal, the front of the same wave belonging to each series will arrive at the same moment at the same point of the ether, and the displacement of the particle will be the sum of those due to the series taken separately. The same will still be the case if one series be in advance of the other by one, two, or any exact number of wave's lengths. If, however, one series be in advance of the other by just half a wave's length, or any odd multiple of half a wave's length, the displacements simultaneously produced in the ether by the two series respectively will always be in opposite directions, and the actual displacement will be only the difference of the two displacements, or zero in case the two are equal, —that is, in case the two streams are of equal intensity. In this way the phenomena of interference admit of the simplest explanation; in short, the fact of interference, as well as its laws, might have been predicted from the fundamental principles of the undulatory theory. The fundamental constant above mentioned evidently represents half the length of a wave of light.

If a portion of the path of either stream lie in glass, or other refracting medium, since according to the undulatory theory the velocity of propagation is slower in such a medium than in air, in the ratio of the refractive index to unity, it follows that the interference must take place as if the stream had described a longer path in air in the above ratio. This agrees with observation.

The laws of interference were applied by Dr. Young to the explanation of the colours of thin plates, and to various phenomena of diffraction [DIFFRACTION], and come into incessant use in the explanation of the phenomena of light. It will be sufficient here to mention a fundamental experiment of Fresnel's, which is easily repeated. Its fundamental character depends upon the circumstance, that in this case the interfering streams neither graze the edge of diffracting bodies, nor are reflected from thin plates, but simply from two ordinary mirrors.

Take two pieces of plate glass, 3 or 4 inches each way, having each a clean edge (that is, pretty free from chipping), and varnish the backs so as to stop the reflection from the second surface. On a block of wood place 6 balls of kneaded wax, and on the balls place the pieces of glass, with their clean edges in contact, so that each piece rests on three balls. By pressing on the balls adjust the mirrors so that their planes make a blunt angle, pointing inwards, of say 179½°. Great care must be taken that neither piece juts out above the other, as the experiment will fail if the mathematical line of intersection of the planes of the mirrors is much removed from the edges in contact. A little jutting is easily got rid of by gently squeezing the wax. Now reflect the sun's light into a darkened room, passing it through a lens of short focus (suppose $\frac{1}{4}$ inch) placed in the window. A second lens may be added at a little distance in case the focal length of the first lens be not short enough to give a sufficiently small image of the sun. Let the light diverging from the image of the sun be reflected, at the distance of a few feet, from the mirrors, at any convenient angle, and at the distance of a few feet from the mirrors examine with a lens the doubly bright portion of the field where the two reflected streams mix. This will be seen traversed by a series of fine bands, called *fringes of interference*, alternately bright and dark near the middle fringe, and coloured on receding from the middle. They are readily distinguished from the vague fringes seen at the edges of the doubly illuminated portion of the field by the blackness of the minima near the centre of the system, and also by their position, as they are always perpendicular to the line joining the two virtual images formed by the light reflected from the two mirrors respectively, and therefore run obliquely across the doubly illuminated portion of the field when the mirrors are adjusted so that the line of intersection of their planes is oblique to the edges in contact. Instead of the mirrors Fresnel used also a flat prism with a very obtuse angle, the fringes in this case being formed by the transmitted light.

The explanation of these fringes follows at once from the principle of interference. The length of the path of either reflected stream is the same as if the light came from the corresponding virtual image of the luminous point. We may suppose therefore that we have two perfectly similar series of waves starting simultaneously from the two virtual images respectively (which we may call I, I'), and mixing within the wedge-shaped portion of space where the reflected streams cross. Any point of a plane bisecting $I\,I'$ at right angles will be equidistant from I and I', and therefore at any such point the two streams will conspire, and that for light of all colours. For any particular kind of light the two streams will again conspire at a point whose distances from I, I' differ by λ, 2λ, 3λ, &c., λ being the wave-length for that kind of light. The locus of such a point will evidently be a hyperboloid generated by the revolution round $I\,I'$ of a hyperbola having I, I' for its foci, and λ, 2λ, 3λ, &c., for its transverse axis. Along the intermediate hyperboloids whose transverse axes are $\frac{1}{2}\lambda$, $\frac{3}{2}\lambda$, &c., the two streams will be in perfect opposition, and will completely neutralise each other. On account of the excessive smallness of λ (which varies from about the one forty-thousandth to the one sixty-thousandth part of an inch in passing from the red to the violet), a section of these hyperboloids by a small plane at the focal distance of the eye-lens will not sensibly differ from a series of equidistant lines parallel to the plane first mentioned. Hence any one kind of light forms a system of parallel bands alternately bright and dark, but the scale of the system decreases from the red to the violet, so that beyond a moderate distance from the central bright fringe, which is common to all the colours, the fringes obliterate each other by overlapping.

We have seen that the phenomena of interference are by no means confined to light. The *beats* for instance heard when two musical notes are very nearly but not exactly in unison, are a phenomenon of interference of sound. For the description of a very elegant experiment rendering the interference of sound a matter of ocular inspection, the reader is referred to a paper by Mr. Hopkins, published in the 5th volume of the 'Transactions of the Cambridge Philosophical Society,' p. 257.

INTERJECTIONS have been defined to be "words used to express some passion or emotion of the mind," as exclamations of joy, grief, astonishment, &c. Interjections however can hardly be considered as a distinct part of speech, but are more properly natural sounds common to all men when laughing, in pain, &c. Many words, such as *malum, macte, profecto*, &c., in Latin, and *adieu, welcome*, &c., in English, which have been considered as interjections by grammarians, ought to be regarded as verbs, substantives, adjectives, or adverbs.

INTERLOCUTORY (*inter*, between, and *loquor*, to speak) a term applied to those judgments, decrees, and orders of courts of law and equity which are made in the progress of a suit before final judgment. Thus, orders for the production of papers, for taking an account of the dealings out of which the dispute arises, are interlocutory orders or decrees. Those judgments which, though they establish the right of the plaintiff, leave the amount of damages to be ascertained by a jury, are generally, but incorrectly, termed interlocutory judgments.

INTERLUDE, a brief piece of church music for the organ, seldom exceeding a few bars, generally produced *ex tempore*, and played after each stanza, except the last, of the metrical psalm. This, being merely for the purpose of giving breathing time to the singers, should always be short and grave, and in keeping with the psalm tune.

Interlude is also the name for a stage-play, among the earliest of the productions of English dramatic literature. It belonged originally to the class of "moralities," and John Heywood, in the time of Henry VIII., was the first to free it from allegorical materials. In modern times the name has been still further extended, and is often applied to a short dramatic piece performed between two others.

INTERMENT, the burial of a dead body in the earth. The manner of disposing of the bodies of the dead has varied in different nations; but the most general modes have been interment in the earth and burning on a funeral pile. The practice of burying is probably the oldest mode, and with most nations has been the ordinary mode of sepulture; but the custom of burning the body, and afterwards collecting the ashes and depositing them in a tomb or urn, became very general among the Greeks and Romans. Among the Greek nations, however, both the burning of the dead and the interment of dead bodies in the earth were practised. The Romans in the earlier periods of their history certainly buried their dead. It is recorded that Sulla was the first member of the Cornelia gens who was burnt. The Egyptians do not seem to have ever adopted the practice of burning the dead; and though, as we have observed, burning became common among the Greeks and Romans, it seems that interment was always practised by the lower orders among the Romans. At Rome, bodies were sometimes buried in pits (puticuli), or thrown to decay in certain unfrequented places. (Varro, 'De Ling. Lat.' v. 25; Horace, 1, Sat. v. 8, &c.) Tacitus (xvi. 6) speaks of the embalming and interment of Poppæa, the wife of Nero, as a deviation from the general practice. The practice of burning the dead appears to have gradually gone into disuse under the Empire: and probably it was never practised by the Christians.

A constitution of the Emperor Justinian (A.D. 537) regulated the expense of funerals in Constantinople. The constitution refers to prior legislation of Constantine and Anastasius. The object of the regulation is well expressed in the following words:—It was to "secure men against the double calamity of losing their friends, and at the same time incurring heavy pecuniary liabilities on their account." Provision was made for securing interment to each person free of cost, and for protecting the surviving friends from the extortion of those who buried the dead. Funds were appropriated for the purpose of interment, which was conducted by persons appointed for the purpose, and with decency, but at little cost. All persons were to be buried alike, with some small allowance in favour of those who wished for a little more display at their own cost; but even this additional expense was limited; and it is said, "thus there will be nothing undetermined; but both those who wish to have funerals on a moderate scale will enjoy the advantages of our rule, and those who wish for more liberal arrangements will not be mulcted heavily, and will be enabled to show their liberality at moderate cost." The whole constitution is very curious; but a full explanation of it would require some labour. The objects of it have, however, been sufficiently stated here. The means by which they were accomplished would not be suitable to this country. ('Novell,' 59.)

At Bombay, says Niebuhr ('Reisebeschreibung,' &c. ii. 50), "the Parsees have a peculiar manner of interring their dead. They do not choose to rot in the earth like the Jews, Christians, and Mohammedans, nor be burnt like the Indians; but they let their dead be digested in the stomachs of birds of prey. They have at Bombay a round tower on a mountain at some distance from the city, which is covered on the top with planks. Here they place their dead, and after the birds of prey have eaten the flesh, they collect the bones below in the tower, and the bones of the men and women in separate vessels." Herodotus (i. 140) says of the ancient Magi, that they never interred their dead till they were torn by birds or dogs. In Herbert's 'Travels' (ed. 1638, p. 54), there is a representation of one of these Parsee towers. Some nations have eaten the aged, and also killed and eaten those who were attacked by disease, and thus anticipated the trouble of interment. This revolting practice is established on sufficient evidence. (Herodotus, i. 216, iii. 99; 'London Geog. Journal,' ii. 199; BATTAS, in GEOG. DIV.) Dr. Leyden states that the Battas frequently eat their aged or infirm relatives, as an act of pious duty. The Battas are not a ferocious, but a quiet and timid people. Niebuhr says in a note to the extract given just above, "At Constantinople I heard, that in the southern part of Russia there is a people who think that they can show to their dead friends and relations no greater honour than to eat them. So different are the opinions of mankind."

These are, however, singular exceptions to the general practices of all nations. Among the Europeans, and those descendants of Europeans who have settled in parts beyond Europe, the interment of the dead in the earth is the universal practice. It was proposed, indeed, to revive the practice of burning during the French revolution, but the proposal was not adopted. It has also been the practice of all nations called civilised, and perhaps of most nations called barbarous, to treat the dead with decency, and to accompany the funeral ceremony with religious rites.

The places set apart for the burial of the dead are generally called cemeteries, which is a Greek term signifying "a place of rest or sleep," and was applied to common places of interment by the early Christians. Among the Greeks, cemeteries were perhaps always without the cities. Among the Romans, the tombs were generally placed by the sides of the public roads. It was an enactment of the Twelve Tables that a dead body was not to be buried or burnt within the city (Dircksen, 'Zwölf-Tafel Fragmente,' p. 657). The prohibition against burning in the city is supposed by Cicero to have been made to prevent risk from fire: the reason for interment not being allowed within the city is not stated. A regulation of the Twelve Tables appears to have limited expenses at funerals (Dircksen, p. 665); and a law to the same effect was passed in the time of the Dictator Sulla (Plutarch, 'Sulla,' c. 35).

The early Christians followed the custom of the Romans in burying outside of cities; but they afterwards transferred their burial-places to the vicinity of the churches and within towns, where they have continuedt o be generally situated up to the present time, the churchyard being the usual place of interment, though, when the church is surrounded by houses, it is by no means a fit situation; for the putrid exhalations arising during the decomposition of animal bodies are injurious to health, and capable of giving rise to, or at least of encouraging, the progress of various pestilential diseases, of which the most common in this country are low nervous or typhus fevers. In all grounds used for interment low wet places should be avoided, and care should be taken that bodies are not interred near wells or rivers from which people are supplied with water.

The subject of interment possesses considerable interest in a legal point of view, for it is often of great importance to determine how long a body has lain in the ground; and by observing the changes which naturally take place in bodies at different stages of decomposition, it is possible in some cases to determine whether certain marks are the result of decomposition, or the remains of injuries inflicted before death.

The subject of interment attracted much attention in England for many years, and a great amount of information was collected by a special inquiry, of which the report was published by Edwin Chadwick, Esq. The report contains, in addition to the evidence on the injurious effects of crowded burial places, much valuable information on the injury to health caused, particularly among the poor, by the delay in interments. Among the poor in some parts of London the average time that a body is kept is about a week, which sometimes arises from inability to raise money for the funeral expenses, as well as other causes; and where there is only a single apartment, the dead and the living occupy it together. The injurious consequences to health from the presence of a dead body, sometimes in a state of rapid decomposition, in a small ill-ventilated apartment, and particularly when death has been the consequence of malignant disease, cannot be disputed; and the moral effect on the living is demoralising. The expense of funerals is another head which is examined in this report, where it is well remarked that "the expense of interments, though it falls with the greatest severity on the poorest classes, acts as a most severe infliction on the middle classes of society." The cost of interment in London varies from 4*l.* for a labourer, to 1000*l.* for a gentleman; for persons of the condition of a gentleman it is stated that 150*l.* would be a low average. But these charges do not include anything except the undertaker's bill. The account of the details of an expensive funeral, "which is strictly the heraldic array of a baronial funeral, the two men who stand at the doors being supposed to be the two porters of the castle, with their staves in black," &c., is ludicrous enough; but the disposition to laugh is checked by considering the pecuniary embarrassment which this absurd display often entails on the survivors.

The recognition of the numerous evils attendant on the usual church and churchyard interments, led, in 1852, to the passing of the Act 15 & 16 Vict., cap. 85, "to amend the laws concerning the burial of the dead in the Metropolis;" and this was followed in the succeeding year by the Act 16 & 17 Vict., cap. 134, for extending the provisions of the Act of 1852 to places beyond the metropolis, in England and Wales. Many other Acts for extending the powers or for regulating minor details have followed.* In 1855 the 18 & 19 Vict., cap. 68, extended the measure to Scotland, and the 19 & 20 Vict., cap. 98 (in 1856), to Ireland.

By these Acts intra-mural interments are rapidly being discontinued. In all towns or poor-law unions burial boards are constituted, with powers to raise funds and provide cemeteries in proper places, to regulate fees, &c., and to keep the burial-places in good order. The secretary of state for the Home department has the power of prohibiting interments in any intra-mural burying-ground which he may deem injurious to the surrounding community, inspectors are appointed, and a system of extra-mural interment is extending itself throughout the United Kingdom. No large towns in England, and few small ones, are now without one or more cemeteries, selected with regard to convenience and their sanitary qualifications; and it is stated that much improvement has been already effected alike in the position and character of the sites selected for the interment of the dead, and in the mode and expense of conducting funerals.

INTERMITTENT. [FEVER.]

INTERNAL and EXTERNAL, geometrical terms applied to the angles made by the sides of a bounded figure. The angle made by two sides is an internal angle; that made by a side and a side produced is an external angle.

INTERNATIONAL LAW. This term was originally applied by Bentham to what was previously called the "law of nations," and it has been generally received as a more apt designation than that which it superseded. When the term "law of nations" was in use, that of "law of peace and war" was sometimes employed as a synonym, and as indicative of the boundaries of the subject. It was thus in its proper sense restricted to the disputes which governments might have with each other, and did not in general apply to questions between subjects of different states, arising out of the position of the states with regard to each other, or out of the divergences in the internal laws of the separate states. But under the more expressive designation, international law, the whole of these subjects, intimately connected with each other as they will be found to be, can be comprehended and examined, and thus several arbitrary distinctions and exclusions are saved. To show how these subjects are interwoven, the following instances are taken:—A port is put in a state of blockade; a vessel of war of a neutral power breaks the blockade: this is distinctly a question between nations, to be provided for by the law of peace and war, in as far as there are any consuetudinary rules on the subject, and the parties will submit to them. But suppose a merchant vessel belonging to a subject of a neutral power attempts an infringement of the blockade, and is seized: here there is no question between nations in the first place. The matter is adjudicated on in the country which has made the seizure, as absolutely and unconditionally as if it were a question of internal smuggling; and it will depend on the extent to which just rules guide the judicature of that country, and not on any question settled between conteuding powers, whether any respect will be paid to what the party can plead in his own favour, on the ground of the comity of nations, or otherwise. But there is a third class of cases most intimately linked with these latter, but which are completely independent of any treaties, declarations of war, or other acts by nations towards each other. They arise entirely out of the internal laws of the respective nations of the world, in as far as they differ from each other. The "conflict of laws" is a term very generally applied to this branch of international law, and the circumstances in which it comes into operation are when the judicial settlement of the question takes place in one country, but some of the circumstances of which cognisance had to be taken have occurred in some other country where the law applicable to the matter is different. One of the most common illustrations of this subject is,—a judicial inquiry in England whether a marriage has taken place in Scotland according to the law of that country; or, an inquiry in Scotland whether a marriage has taken place according to the law of England; in either of which cases there will generally be the further and nicer question, Which country's law ought to prevail as the criterion?

Thus the three leading departments of international law are—

1. The principles that should regulate the conduct of states to each other.

2. The principles that should regulate the rights and obligations of private parties, arising out of the conduct of states to each other.

3. The principles that should regulate the rights and obligations of private parties, when they are affected by the separate internal codes of distinct nations.

The first of these has been the principal subject of the well-known works of Grotius, Puffendorf, Vattel, and other publicists, who have derived from general principles of morality and justice a series of minute abstract rules for the conduct of nations towards each other, and subsidiarily for the conduct of their subjects in relation to international questions.

It is clear that thus in its large features, as a rule for the conduct of independent communities towards each other, the law of nations wants one essential feature of that which is entitled to the term law—a binding authority. Nations even the most powerful are not without checks in the fear of raising hostile combinations and otherwise; but there can be no uniformity in these checks; and in general when the interest is of overwhelming importance, and the nation powerful, it takes its own way. The importance of the questions which may be involved in the law of nations thus materially affects the question how far it is uniformly obeyed. In many minor questions,—such as the safety of the persons of ambassadors, and their exemption from responsibility to the laws of the country to which they are accredited, and in other matters of personal etiquette, a set of uniform rules has been established by the practice of all the civilised world, which are rarely infringed. But in the more important questions,—regarding what is a justifiable ground for declaring war? what territory a nation is entitled to the sovereignty of? what is a legitimate mode of conducting a war once commenced? &c.—the rules of the publicists are often precise enough; but the practice of nations has been far from regular, and has been, as every reader of history knows, influenced by the relative strength of the disputing parties more than by the justice of their cause. The later writers on this subject have from this circumstance directed their attention more to the means by which any system of international law can be enforced, than to minute and abstract statements of what may be theoretical justice, but has little chance of being enforced. They have found several circumstances which have an influence in the preservation of international justice, though of course no sanctions which can give it the uniformity and consistency of internal laws.

The combinations for the preservation of what is called the Balance of Power [BALANCE OF POWER] are among the most useful restrictions of ambition. All periods of history furnish illustrations of this principle. Hume found that the Peloponnesian war was carried on for the preservation of the balance of power against Athens. The war with the French Republic and Empire exhibited a noted illustration of combination to prevent universal conquest on the part of the

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* These have been collected, with notes and explanatory remarks, under the title of 'Burial Acts, Metropolitan and Provincial,' &c., by J. J. Scott, Esq. (Knight & Co., Fleet Street).

French. The late war with Russia exhibited a similar attempt to prevent the aggrandisement of Russia at the expense of Turkey. The safety of small states from being absorbed by their larger neighbours thus lies in the jealousy which their neighbours feel of each other's aggrandisement. So the jealousy of rulers is one barrier to national injustice. Another is public opinion: sometimes that of the nation whose rulers would be prepared to commit injustice—sometimes that of other nations. Of course it can only be to a very limited extent that the public feeling of a despotic government can check the grasping spirit of its rulers; but the public feeling of the constitutional and democratic states is the great check on the injustice that might be perpetrated by a nation when it becomes so powerful as Great Britain.

The seizure of the Danish fleet by the English during the war with Napoleon has been a subject of warm censure. Necessity—even the plea that Napoleon would have used the fleet to invade our own shores—has not been accepted in palliation of the act; and the manner in which it has been canvassed is very likely to prevent any government from adopting the precedent. The partition of Poland is an instance of national injustice condemned by the public feeling of countries other than those by which it was perpetrated; and it may be questioned whether the states which accomplished the partition may not yet suffer by it. Good fame in the community of nations is like respectability in private circles, a source of power through external support; and the conduct of Russia towards Poland has frequently diverted from the former the sympathy of free nations. It need scarcely be observed that the press, whether fugitive or permanent, is the most powerful organ of this public opinion, and that the views of able historians, jurists, and moralists, have much influence in the preservation of international justice.

Among the principal subjects of dispute in this department of international law are—the sovereignty of territory and the proper boundaries of states; questions as to discovery and first occupancy of barbarous countries; questions as to any exclusive right to frequent certain seas,—and here there is a well-known distinction between the broad ocean and the narrow seas that lie close to particular territories; questions regarding the right of navigation in rivers which may be either between the upper and lower territories, or between states on opposite banks; questions as to the right of harbour or fishing, &c.; and questions as to the right of trading with particular states. A very advantageous method of adjusting minor international disputes has been frequently had recourse to of late in a submission to the arbitration of a neutral power. Pride and the spirit of not yielding to intimidation or aggrandisement have often more influence in the resistance offered by one state to the claim of another, than the desire to keep what is demanded. In such a case the national pride is not injured when that which is yielded to is the award of a neutral party, not the demand of an opponent. It has been suggested by Bentham and Mill that the civilised states of the world should establish among themselves a congress, which should adjudicate on all disputes between its members, the members being excluded from voting in their own disputes.

The Second department into which international law is divided—the rights and obligations of individuals as affected by the conduct of states towards each other—has, like the first, been examined by the publicists in their theoretical manner; but it has never, perhaps, received so much practical illustration as it did in the British courts, particularly the Prize Court, during the war with France. In a despotic country it would of course scarcely ever occur that the bench should fail to give effect to the national policy of the government, whatever that may be. But in England it was the rule that foreigners as well as natives were entitled to the rigid administration of the law, and that, if the proceedings of the government were at variance with the rights of parties according to the law of peace and war, individuals might have redress. Thus, when Great Britain, in opposition to the Berlin decrees, tried to establish a "paper blockade," that is to say, by force of orders in council to declare places to be under blockade, whether there were a force present to support it or not, Sir William Scott found that "in the very notion of a complete blockade, it is included that the besieging force can apply its power to every point in the blockaded state. If it cannot, it is no blockade of that quarter where its power cannot be brought to bear."

It has frequently been observed, that as to all departments of the law of nations, uncivilised countries are at the mercy of the civilised: that not having any means of reciprocating the action of international laws, from their having no systematic judicatories of their own, they have not even the frail tenure of generally received opinions as to what the conduct of independent nations towards each other ought to be, for their protection. This is in some measure true. If a weak civilised nation, which can eloquently appeal to the law of nations, is feebly protected against the injustice of a strong nation, still less effectually is a barbarous community, which never heard of international law, and knows not how to appeal to its acknowledged principles, protected by it; and, in regard to such communities, the humanity and conscience of the powerful nations coming in contact with them are their protection, rather than any rules of international law. Thus when, as in the instance of a colonial government or otherwise, such a nation as the British has to deal with the inhabitants of a barbarous country, it cannot be said that these inhabitants have the law of nations to appeal to if they are unjustly treated, and there is no security for their being well and humanely used but the morality and conscience of the British nation and its government. How far civilised nations had in former times disregarded all feelings of common humanity in their intercourse with inferior races, the history of colonisation, and especially that relating to the continent of America, is a horrible record. In later days higher notions have been entertained of the responsibility of superior power, and the civilised man has in some measure ceased to make his first advances to the notice of the barbarian in the character of a murderer and a pillager. England has in this improved morality so far advanced before other nations, as to be the protector of barbarous races from the oppression of others, in her efforts for the abolition of the slave trade and the preservation of aboriginal nations. These efforts, in so far as they are an anomaly in the general conduct of nations, have introduced some necessary exceptions to the rules of international law applicable to the rights of persons. This has consisted in the necessity of treating those who are injured by the slave trade, namely, the slaves carried off, as if they were subjects of this country subjected to injury, while the deporters have likewise been of necessity treated in the general case as if they were subjects of this country doing the injury. The effect of this state of matters, as an exceptional principle in international law, sometimes occasions difficult questions. In one case a foreign slaver had been captured and taken possession of. The crew rose, and putting the captors to death, recaptured the vessel. They were tried and condemned to death for murder in an English court; the judge refusing to admit the plea that, as the capture had taken place under our laws, not their laws, they were entitled to regain possession by any means which they chose to adopt. He held it right, in fact, to treat the ship as a prison, and the captured seamen as persons in a British prison. On the question, however, coming before the judges, the conviction was quashed, the ground of reversal being, that the vessel not having slaves on board was not liable to seizure. In those cases where it is necessary to diverge from the general principle of international law, for the protection of the weak, it is fortunate that the humane and enlightened motive of proceeding is a guarantee for its being beneficially exercised.

The rights of individuals have sometimes been so much affected by the conduct of nations towards each other, that their own nation has been induced to make war against the nation aggressing. This has twice occurred in our intercourse with America: one war was caused by our restrictions on the commerce of America by the orders in council; another by our searching American merchant vessels for British seamen. This subject of "the right of search," as it is termed, is still in an unsatisfactory and unsettled state.

The Third division of international law is that which most properly comes under the head "Conflict of Laws," namely, the principles that ought to regulate the rights and obligations of private parties when they are affected by the separate internal codes of distinct nations. This involves questions with individuals, and not, at least in the first instance, questions with states; and the adjustment of each question depends on the view taken by the law of the country to which the individual or his property is amenable. But it has this distinctive feature, that the circumstances under which disputes arise are not in the conduct of one nation towards another, but in differences between the internal laws of the countries, which internal laws disagree, not because the one nation has a dispute with the other, but in the general case because its legislators have taken its internal situation solely into consideration, and have overlooked the existence of other nations. There can be no part of the world where this species of international law can be so well illustrated as in the United States—a collection of communities, each having an internal system of administration, but each acting on principles of harmony and alliance with the other states of the Union. It is thus natural that America should have produced the best work on the subject, in Professor Story's 'Commentaries on the Conflict of Laws Foreign and Domestic, in regard to Contracts, Rights, and Remedies; and especially in regard to Marriages, Divorces, Wills, Successions, and Judgments,' of which two editions are now known and esteemed in this country. The leading rule of international law in this department is, that each civilised nation is to give efficacy to the laws of another country, unless its own laws or the general principles of justice are thereby invaded. We have the broadest and most distinct illustrations of this rule in the criminal law. The progress of opinion has lately been in favour of each nation rendering back fugitive criminals, to be dealt with according to the law of the country where they have committed any private crime against person or property. In conformity with this principle, treaties have been made with several states, for enforcing which, in this country, acts of parliament have been passed enabling the secretary of state, on the requisition of the ambassador or other representative, to issue a warrant to magistrates to seize a person accused of a crime, a magistrate being enjoined to put it in force on his being satisfied that the charge is of such a nature as would authorise him to commit a person charged with perpetrating it in his own jurisdiction. [Convention Treaties.]

But it has been a rule in many countries, and particularly in our own, that no aid is to be given for the enforcement of the political laws of foreign states. And hence as in other branches of international law, our enlightened principles on the subject of slavery have here been the cause of perplexing difficulties. With slave-holding countries slavery comes to be a question of property, but with us it can only be a question of government; and we cannot view any rules regarding property in slaves as laws relating to private rights, an infringement of which, when held to be criminal in the slave-holding country, must be so also here. Accordingly in the celebrated case of the Creole, in 1841, when certain American slaves escaped and found protection in a British settlement, it was found that we could not send them back to their owners as robbers who had with violence stolen their own persons from the custody of their proprietors.

As on the one hand the criminal law is that to which this department of international law most broadly and distinctly applies, on the other hand the position of real or landed property is that to which it has generally the least reference. The reasons of this distinction are obvious: his own personal conduct is that object of the law which a man most completely carries about from one country to another; his connection with landed property is the relation in which a tribunal out of the country in which the property is, can have the least chance of adjudicating. Between these extremes there are many questions regarding persons in their relations to each other, and regarding contracts as to moveable or personal property. It came thus to be a general principle, that rights connected with landed property must always be settled by the law of the place where the land lies, while questions regarding other property might be subjected to other criterions of jurisdiction. Perhaps historical circumstances in the early history of the European nations favoured this division. The various tribes which occupied the territory of the Roman empire appear to have carried with them their own peculiar laws and customs. (Savigny quotes a letter from Bishop Agobardus, in which he says it often happens that five men, each under a different law, may be found walking or sitting together—a state of society at this day exemplified in some oriental nations.) Among all these distinct tribes the feudal system arose as the general and uniform territorial law; while by reason of circumstances which need not be here narrated, the civil law became the ruling principle as to persons in their relation to each other when that relation was not of a feudal character, and as to claims regarding moveable goods. The common law of England has, from other circumstances, the least affinity with the other European codes in respect to personal relations. But it has fortunately happened that those departments of the law with which international questions are chiefly concerned,—the consistorial and the admiralty law, have been considered as the legitimate offspring of the civil law, and have adopted in a great measure its principles as they have been in practice throughout Europe. The mercantile law of England again has accommodated itself to the custom of merchants; this custom arising, in a great degree, out of the adaptation to modern commerce of the principles of the civil law (the portion of it least in harmony with that of other countries being the bankruptcy law, which is entirely statutory), has consequently adapted itself to the exigencies of foreign commerce.

The conflicts of laws between England and Scotland are to us of course the most important and interesting. The consuetudinary law of England has perhaps fewer principles in common with that of Scotland than the latter has with the law of any other country in Europe; and this divergence has been the cause of many difficult questions. In these the law of marriage and that of succession have been particularly fertile. In the former the difference between the institutions of the two countries, when subjected to the principles of international law, has been productive of very remarkable effects. On the subject of succession fortunately a series of decisions in both countries has settled two very important principles—that in the case of landed property it follows the *lex rei sitæ*, or the law of the place where the property is; while in moveable or personal property it follows the *lex domicilii*, or law of the domicile in which the person leaving it died.

INTERPLEADER, the name of an action at law, and of a proceeding in equity. When a person holding goods, or owing a debt or duty, is sued by two or more claimants, the court will order them to interplead upon the application of the party sued, and upon his delivering up or offering to deliver up the matter in dispute, and disclaiming all interest therein. The Sheriff when goods seized by him are claimed by some other person than the execution debtor, may also interplead, to have the right ascertained. A similar process is in use in the County Courts.

INTERPOLATION. Every mathematical table consists of a series of values of some algebraical expression corresponding to equidistant values of the letter on which it depends. Thus, the most extensive table of logarithms in common use is a succession of values of log. x, answering to $x = 10{,}000$, $x = 10{,}001$, $x = 10{,}002$, and so on up to $x = 99{,}999$. The process of interpolation is that of inserting in a table values of the tabulated function intermediate to those given in the table. For example, suppose that p, q, r, s, &c., are written in a table opposite to a, $a + b$, $a + 2b$, $a + 3b$, &c., and it is demanded what is the value of the function corresponding to $a + 2\frac{1}{2}b$: this is a question of interpolation.

Such a question can only be solved approximately, but, generally speaking, the values in the table are themselves but approximations, and the interpolated values are as correct as the tabular ones. Strictly speaking, the question itself is indeterminate, for no function can be determined by means of any finite number of values, however great. The question is precisely analogous to that of drawing a curve through a given number of points, which may be done in an infinite number of ways, how many points soever there may be. But if the points be gradually increasing in distance from a given line, and if it be a condition that the intermediate points must do the same, then if the points be near together, any two curves which satisfy the conditions must very nearly coincide. If equidistant abscissæ of such a curve be tabulated with their ordinates, then the ordinates corresponding to intermediate abscissæ will be very nearly the same for any curve which can pass through the points which belong to the tabulated ordinates.

The method of interpolation consists entirely in the application of the following theorem. [DIFFERENCE.] Let p, q, r, s, t, &c., be terms of a series corresponding to a, $a + b$, $a + 2b$, &c., and let the successive differences be formed, as in the following table:

$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$
a	p			
		Δp		
$a+b$	q		$\Delta^2 p$	
		Δq		$\Delta^3 p$
$a+2b$	r		$\Delta^2 q$	
		Δr		$\Delta^3 q$
$a+3b$	s		$\Delta^2 r$	
		Δs		$\vdots$
$a+4b$	t		$\vdots$	
$\vdots$	$\vdots$	$\vdots$		

where Δp is $q-p$, &c., $\Delta^2 p$ is $\Delta q - \Delta p$, &c. Then the nth term reckoned from p exclusive is

$$p + n\,\Delta p + n\,\frac{n-1}{2}\,\Delta^2 p + n\,\frac{n-1}{2}\,\frac{n-2}{3}\,\Delta^3 p + \text{\&c.} \quad \text{(A).}$$

Thus q is $p + \Delta p$, r is $p + 2\Delta p + \Delta^2 p$, and so on. This series, which gives the rest of the table accurately, will give the intermediate values approximately, if p, Δp, $\Delta^2 p$, &c., diminish rapidly. Thus, by making $n = \frac{1}{2}$, we find the term which should stand opposite to $a + \frac{1}{2}b$, if the table were made twice as minute as it now is, or, as we may say, *bisected*: if $n = 2\frac{1}{2}$, we find the term answering to $a + 2\frac{1}{2}b$, and so on. The following is an instance:—

Given the present value of 1,000,000*l.* 20 years hence, at 2, 4, 6, 8, and 10 per cent.: to deduce from thence an approximation at the rate of $4\frac{1}{2}$ per cent. Let it be observed, that from 2 to $4\frac{1}{2}$ is one interval and a quarter of the tables, or $n = 1\frac{1}{4}$.

2	672971				
		− 216584			
4	456387		+ 72002		
		− 144582		− 24677	
6	311805		+ 47325		+ 8705
		− 97257		− 15972	
8	214548		+ 31353		
		− 65904			
10	148644				

We have taken this example to show, when the intervals of the tables are considerable, how slowly the differences may diminish. The consequence is that only four places of the result will be correct. We have now

$$p = 672971 \qquad \Delta^3 p = -\,24677$$
$$\Delta p = -\,216584 \qquad \Delta^4 p = +\,8705$$
$$\Delta^2 p = +\,72002$$

$$n = \frac{5}{4},\quad \frac{n-1}{2} = \frac{1}{8},\quad \frac{n-2}{3} = -\,\frac{1}{4},\quad \frac{n-3}{4} = -\,\frac{7}{16},$$

$$n\,\frac{n-1}{2} = \frac{5}{32},\quad n\,\frac{n-1}{2}\,\frac{n-2}{3} = -\,\frac{5}{128},$$

$$n\,\frac{n-1}{2}\,\frac{n-2}{3}\,\frac{n-3}{4} = \frac{35}{2048}.$$

$$\begin{array}{rrr}
 & & 672971 \\
\frac{5}{4} \times & -216584 = & -270730 \\
\frac{5}{32} \times & 72002 = & +\;\;11250 \\
-\frac{5}{128} \times & -\;24677 = & +\;\;\;\;964 \\
\frac{35}{2048} \times & 8705 = & +\;\;\;\;149 \\
\hline
 & \text{Answer} & 414604 \\
 & \text{Correct Answer} & 414643
\end{array}$$

The smaller the tabular interval, the more correctly will a given number of differences serve to make the interpolation. Let us take the preceding question on the supposition that the rates are 2, 3, 4, 5, and 6 per cent., in which from 2 to $4\frac{1}{2}$ is $2\frac{1}{2}$ intervals, or $n=2\frac{1}{2}$.

$$\begin{array}{c|lllll}
2 & 672971 & & & & \\
 & & -119295 & & & \\
3 & 553676 & & +22006 & & \\
 & & -97289 & & -4215 & \\
4 & 456387 & & +17791 & & +838 \\
 & & -79498 & & -3377 & \\
5 & 376889 & & +14414 & & \\
 & & -65084 & & & \\
6 & 311805 & & & &
\end{array}$$

$$n=\frac{5}{2},\ n\,\frac{n-1}{2}=\frac{15}{8},\ n\,\frac{n-1}{2}\,\frac{n-2}{3}=\frac{5}{16},$$

$$n\,\frac{n-1}{1}\,\frac{n-2}{3}\,\frac{n-3}{4}=-\frac{5}{128}.$$

$$\begin{array}{rrrr}
 & & & 672971 \\
\frac{5}{2} & \times -119295 & = & -298238 \\
\frac{15}{8} & \times +22006 & = & +41261 \\
\frac{5}{16} & \times -4215 & = & -1317 \\
-\frac{5}{128} & \times +838 & = & -33 \\
\hline
 & & \text{Answer} & 414644 \\
 & & \text{Correct Answer} & 414643
\end{array}$$

The most simple interpolation is that which takes first differences only into account, and is perfectly well known to every one who can use a table of logarithms, or interpose arithmetical means.

We now give some instances in which the intermediate terms are expressed by means, not of the differences of given terms, but of the terms themselves. The case which most often occurs is that in which it is required to bisect the interval of the tables, and in this case a rule may be given which amounts to using the *third* differences, and is extremely simple. Let p, q, r, and s be successive terms of a table, and let it be required to find the term intermediate between q and r, that is, if q and r stand opposite to x and $x+y$, required the term answering to $x+\frac{1}{2}y$. The following formula shows the process :—

$$\frac{q+r}{2}+\frac{(q+r)-(p+s)}{16}\ \ldots\ (\text{B}).$$

Thus in the preceding instance—

$$\begin{array}{rr}
p=553676 & q+r=833276 \\
q=456387 & p+s=865481 \\
r=376889 & 4)-32205 \\
s=311805 & 4)-8051 \\
 & -2013 \\
 & \frac{1}{2}(q+r)=416638 \\
 & \text{Answer}\ \ 414625
\end{array}$$

This more simple rule is equivalent to the use of the preceding method with p and its first three differences. It requires that two terms should lie on each side of the term sought; but if it were required to bisect the interval between p and q by means of p, q, r, and s, the formula is as follows :—

$$q-\frac{5(r-p)-(s-q)}{16}\ \ldots\ (\text{C})$$

Thus, to find the value at $3\frac{1}{2}$ per cent. from the preceding data, we have—

$$\begin{array}{rr}
r-p= & -176787 \\
 & 5 \\
\hline
 & -883935 \\
s-q= & -144582 \\
\hline
5(r-p)-(s-q)= & 4)-739353 \\
 & 4)-184838 \\
 & -46210 \\
q= & 456387 \\
\hline
\text{Answer} & 502597 \\
\text{Correct Answer} & 502566
\end{array}$$

The formula for the bisection of the interval of r and s by means of p, q, r, and s, is—

$$r+\frac{5(s-q)-(r-p)}{16}\ \ldots.\ (\text{D}).$$

Where extreme accuracy of bisection is required, the following rule will be equivalent to going as far as fifth differences, and taking from the table three terms on each side of the intermediate term required.

Let the terms of the table be p, q, r, s, t, and u, the intermediate term of r and s being required.

$$\begin{array}{ccc}
p & q & r \\
u & t & s \\
\hline
u+p=x & t+q=y & s+r=z
\end{array}$$

$$\text{Intermed. term}+\frac{z}{2}+\frac{25(z-y)+3(x-z)}{256}\ \ldots.\ (\text{E}).$$

As an instance, take from the article Interest the logarithms to ten places of 1·01, 1·02, 1·03, 1·04, 1·05, and 1·06, for p, q, r, s, t, and u, neglecting decimal points and preliminary ciphers.

$$\begin{array}{rrr}
43213738 & 86001718 & 128372247 \\
253058653 & 211892991 & 170333393 \\
\hline
x=296272391 & y=297894709 & z=298705640 \\
298705640 & & 297894709 \\
\hline
-2433249=x-z & & z-y=\ 4)81093100 \\
3 & & 20273275 \\
\hline
-7299747 & & -7299747 \\
 & & 8)12973528 \\
\frac{1}{2}z=\ 149352820 & & 8)\ 1621691 \\
50678 & & 4)\ 202711{\cdot}4 \\
\text{Ans.}\ \ {\cdot}0149403498=\text{log. }1{\cdot}035 & & 50677{\cdot}9
\end{array}$$

The formula (B) is sufficient to bisect the intervals given in the article cited.

The following is the method by which the formula (A) may be expressed in terms, not of p, $\triangle p$, &c., but of p, q, r, &c. Suppose this is to be done as far as the third difference, or in terms of p, q, r, and s. Assume for the function in question

$$\text{A}\,(n-1)(n-2)(n-3)+\text{B}\,n(n-2)(n-3)+\text{C}\,n(n-1)(n-3)+\text{D}\,n(n-1)(n-2).$$

When $n=0$, this should be p; but it then becomes $-6\,\text{A}$, whence $\text{A}=-\frac{1}{6}p$. When $n=1$, this should be q; but it then becomes $2\,\text{B}$, whence $\text{B}=\frac{1}{2}q$. Similarly $\text{C}=-\frac{1}{2}r$, and $\text{D}=\frac{1}{6}s$: or the function tabulated, within the given limit, is, so far as third differences can determine it,

$$n(n-1)\left\{\frac{n-2}{6}s-\frac{n-3}{2}r\right\}$$

$$+(n-2)(n-3)\left\{\frac{n}{2}q-\frac{n-1}{6}p\right\}$$

This method may be extended to the interpolation of intermediate values, when the given values are not equally distant. Suppose that according as n is a, b, or c, a function is p, q, or r. Assume for the function

$$\text{A}\,(n-b)(n-c)+\text{B}\,(n-a)(n-c)+\text{C}\,(n-a)(n-b).$$

Then when $n=a$, we must have $\text{A}\,(a-b)(a-c)=p$, or

$$\text{A}=\frac{p}{(a-b)(a-c)};\ \text{B}=\frac{q}{(b-a)(b-c)};\ \text{C}=\frac{r}{(c-a)(c-b)}.$$

The following results will serve as an instance of the application of the last method but one. Suppose it required to interpose four equidistant values between q and r in the series p, q, r, s, using third differences inclusive. First interpose four arithmetical means between q and r, and let them be A, B, C, D: then interpose four arithmetical means between $3q-2p-s$, and $3r-2s-p$, and let these be A′, B′, C′, and D′. Then the four terms intermediate between q and r must be

$$\text{A}+\tfrac{8}{300}\text{A}',\ \text{B}+\tfrac{4}{100}\text{B}',\ \text{C}+\tfrac{4}{100}\text{C}',\ \text{D}+\tfrac{8}{300}\text{C}'.$$

If it be required to interpose three equidistant values between q and r, using third differences, take p, q, r, s, and between q and r interpose three arithmetical means, A, B, and C; also between $3q-2p-s$ and $3r-2s-p$ interpose three means, A′, B′, and C′. Then the three terms required are

$$\text{A}+\tfrac{1}{32}\text{A}',\ \text{B}+\tfrac{1}{24}\text{B}',\ \text{C}+\tfrac{1}{32}\text{C}'.$$

To interpose two terms, still with third differences, find two arithmetical means between $30q-2p-s$ and $30r-2s-p$; the twenty-seventh parts of these means are the intermediate terms required. The interpolation of one term has already been given (B).

When second differences only are used, no material simplification of the fundamental rule can be given. To place k intermediate terms between q and r by means of q, r, and s, interpose k arithmetical means, and correct them as follows. Calculate $(q+s-2r)\div 2(k+1)^2$, and call this A; then subtract from the several means

$$k\,\text{A},\ 2(k-1)\,\text{A},\ 3(k-2)\,\text{A},\ \ldots\ (k-1)\,2\,\text{A},\ k\,\text{A}.$$

It would be a little more correct to let A be $(p+r-q-s)\div 4(k+1)^2$, which in the case of a single intermediate term would amount to using third differences.

INTERPRETATION. (Mathematics.) This word is coming into use as descriptive of a process which it has long been customary to employ, though without any express name. When an algebraical definition is laid down, there is frequently some restriction implied in the manner of making the definition, so that the process to which it leads presents more cases than can be explained by it, or were contemplated when it was made. For example, the abbreviation of a, aa, aaa, &c. [Exponent] into a, a^2, a^3, and the rules which spring from it, soon lead to such results as—

$$a^{-3}, \quad a^{0}, \quad a^{\frac{1}{2}}, \quad a^{-\frac{1}{2}};$$

which, though they follow from algebraical processes, yet when they first arrive, are without algebraical meaning. In such a case, the process of interpretation enters; the question is, What should such symbols mean? have they a necessary meaning? if not, is there any meaning which will be more convenient than another? A definition has been laid down, leading to results which cannot be explained by it: required the extension of the definition which will enable it to explain its own results.

Examples are found in all works which explain the principles of algebra. The rule always is, let the interpreted meaning of the new symbols be such as will make the whole of the process true by which they were obtained. Now as they must have been obtained by the application of those formulæ which are true of the intelligible results of the definition, the rule just mentioned leads to the following: let the meaning of the unintelligible results be such as will make the formulæ of the intelligible ones true of them. Thus, in the preceding instance, the fundamental formula which connects the terms of the series a, a^2, a^3, a^4, &c., is—

$$a^{m} \times a^{n} = a^{m+n}$$

which is intelligible when m and n are positive whole numbers, Suppose it now required to interpret a^{0}: that is, to give it a meaning which shall make the preceding formula true of it. Write 0 instead of m and we have $a^{0} \times a^{n} = a^{0+n} = a^{n}$, or a^{0} must stand for 1. Again, suppose it required to interpret $a^{\frac{1}{2}}$. In order that the preceding formula may be true of the meaning of $a^{\frac{1}{2}}$, we must have

$$a^{\frac{1}{2}} \times a^{\frac{1}{2}} = a^{\frac{1}{2}+\frac{1}{2}} = a^{1} \text{ or } a$$

whence $a^{\frac{1}{2}}$ must stand for $\sqrt{a}$. And similarly for other cases.

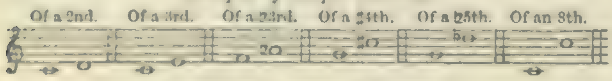
It is interpretation which creates the distinction between algebra, as now known, and arithmetic with general symbols of number, or universal arithmetic. This we shall see in the article Negative and Impossible Quantities.

INTERROGATORIES. [Equity.]

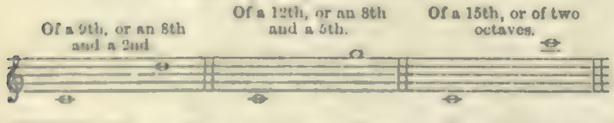
INTERVAL, in Music, is described by Dr. Robert Smith, in his 'Harmonics,' as "a quantity of a certain kind, terminated by a graver and an acuter sound." Brossard has said the same thing in other words:—"C'est la différence, ou distance, qu'il y a d'un son grave à un son aigu." Agreeing in this definition, from C to D is an interval of a 2nd; from C to G an interval of a 5th; from C to B♭ an interval of a flat 7th, &c. [Scale.]

Intervals are *simple* when confined within the octave, *compound* when they exceed it, and are named according to the distance of the two boundary notes. Thus the interval of a whole tone (C D) is called a 2nd; of a whole tone and a semitone (C E♭), a minor 3rd, &c. Intervals, therefore, are considered as sounds, and hence are either consonant or dissonant; that is, concords or discords. [Concord; Discord.]

Examples of Simple Intervals.



Examples of Compound Intervals.


Of a 9th, or an 8th and a 2nd
Of a 12th, or an 8th and a 5th.
Of a 15th, or of two octaves.

INTESTACY is either the dying without a will, or leaving a will which does not dispose of the whole of the real or personal estate. There may therefore be either a general or a partial intestacy.

INTONATION, in Vocal Music, is the tuning of the voice—the singing true or false—in tune or out of tune. Correct *intonation* is the first requisite in a singer; this wanting, all his other musical qualities, however good, are unavailing.

INTRADOS and EXTRADOS, the lower and higher curves of an arch. The intrados of an arch is also called the *soffit*. The intrados and extrados are measured respectively along the inside and outside of the voussoirs. [Arch.]

INTUITION (*intueri*), the most simple act of the reason or intellect, on which, according to Locke, "depends all the certainty and evidence of all our knowledge; which certainty every one finds to be so great, that he cannot imagine, and therefore cannot require, a greater. For a man cannot conceive of a greater certainty than that any idea in his mind is such as he perceives it to be, and that two ideas, wherein he perceives a difference, are different and not precisely the same." His definition, or rather explanation, of intuition is as follows:—"Sometimes the mind perceives the agreement or disagreement of two ideas immediately by themselves, and this, I think, we may call intuitive knowledge. In this the mind is at no pains of proving or examining, but perceives the truth as the eye does the light, only by being directed to it." ('Essay on Human Understanding,' b. iv., c. ii., § 1.) Sir W. Hamilton ('Lectures on Metaphysics,' lect. xxiii.) observes that "an intuitive cognition, as an act, is complete and absolute, as irrespective of aught beyond the dominion of consciousness; whereas a representative cognition, as an act, is incomplete, being relative to and vicarious of an existence beyond the sphere of actual knowledge."

The nature of the relation which subsists between intuition and reasoning has been strongly contested. While Beattie maintains that the connection between them, how closely soever they are found in general to be connected, is not necessary, but, on the contrary, a being endued with one may be destitute of the other; Dugald Stewart, on the other hand, insists that the two are not radically distinct, although by most writers they are considered to be different faculties. Locke having rightly maintained that every step which the reason makes in demonstrative knowledge has intuitive certainty, and that, consequently, the power of reasoning presupposes that of intuition, Stewart thinks that the intuition of Locke implies the power of reasoning; or, at least, that intuition combined with memory explains reasoning. Here his usual sagacity appears to have failed Stewart. While the mind itself is perfectly simple, it has been, for the purpose of attaining accuracy of language and distinctness of theory, supposed to be multiple; and distinct faculties have been ascribed to it according as its several operations comprise more or fewer elements. According, therefore, to his own account, reason, which involves the element of time, must be kept distinct from intuition, which does not involve that element.

The proper objects of intuitive certainty are identical propositions. This, of course, does not mean propositions verbally identical; such as "a man is a man." But while the object of thought is perfectly and always one, it may present itself to the thought under a variety of aspects, either dissolved into its elements or as combined into a whole. It is this identity under an apparent diversity that constitutes that original and primary evidence which makes certain propositions, as soon as the respective terms are understood, to be perceived intuitively. On the other hand, the apparent identity of a real diversity is the ground of all sophistical argument. The ultimate form of legitimate argumentation is, $a = b$, $b = c$, $\therefore a = c$. But every fallacy, when detected, will invariably be found to be $a = b \pm r$, $b = c$, $\therefore a = c$. The sophistry consists in the suppression of the element r, either positive or negative.

INULA HELENIUM (Elecampane), an indigenous perennial herbaceous plant, found in most meadows, the root of which is used in medicine. This part is thick and branching, brown externally, white internally, with an aromatic odour and a mucilaginous taste, at first bitter, afterwards sharp and camphor-like. In addition to mucilage it contains a large quantity of a variety of starch termed *inulin*. Inulin exists in many other plants, and goes by a variety of names,—Alantin, Menzanthin, Elecampanin, Dahlin, Datiscin. *Inula helenium* also contains a volatile oil, a portion of which when crystallised constitutes the stearopten called Elecampane camphor; a bitter extractive; an acrid resin; some salts of lime, &c.

These ingredients give it a tonic and stimulating property, and it is employed in debility of the stomach and other diseases of mucous surfaces unattended with inflammation. It is, however, not much used. Having kept its place in popular favour from the time of the earliest Greek writers, it cannot be deemed altogether useless. It affords a ready substitute for senega, the virtues of which are greatly lessened by age, and can rarely be had fresh. The *Inula conyza*, formerly *Conyza squarrosa*, a plant not uncommon by the sides of fields or roads in chalky districts, is deservedly esteemed in the east of Europe as an antidote against the bites of vipers. It is remarkable that such an antidote has, in different parts of the world, been supposed to be found in the tribe of *Compositæ*, such as *Mikania guaco*, *Eupatorium agapana*, *Inula viscosa*, *Prenanthes serpentaria*, *Vernonia altissima*, &c.

INULIN, *Dahlin*, *Alantin*, *Menzanthin*, *Datiscin* ($C_{12}H_{10}O_{10}$?), a neutral vegetable principle, resembling starch in many of its properties; it exists in the root of elecampane (*Inula helenium*), the *Helianthus tuberosus*, the *dahlia*, and some other plants. The roots are reduced to a pulp, which is to be placed on a very fine sieve, and a stream of water is to be poured upon it as long as the latter is rendered milky; the inulin is then allowed to deposit; the supernatant liquor being poured off, the deposit is to be repeatedly washed with water till it comes off perfectly limpid.

Inulin when dry has the following properties:—It is a white brittle mass composed of crystalline grains, or else a fine and white powder, which adheres to the teeth. It is insipid, insoluble in cold water, but very soluble in boiling water; the solution is fluid, and not gelatinous like that of starch. When it is very dilute, it does not become turbid on cooling; but alcohol, not being a solvent of inulin, precipitates it from this solution. When heated to above 212°, it melts, and is converted into a sweetish mass which is very soluble in cold water (*pyro-inulin*). Cold sulphuric or nitric acid converts it into the same substance.

Iodine renders inulin of a brown tint, which is fugitive. Lime-water, solution of tin, subacetate of lead, tincture of galls, protosalts of mercury, and salts of silver, do not precipitate the solution of inulin; the alkalies act upon it as they do on starch.]

Dilute boiling sulphuric acid converts inulin rapidly into glucose; this effect is also produced when inulin is heated alone: the glucose produced undergoes the spontaneous fermentation when mixed with yeast.

INVARIABLE (Mathematics), the same word in meaning as CONSTANT, which see. There are however two sorts of constants, which it is desirable to treat under different names: the first, which we may call a constant, or a common constant, meaning a quantity which is absolutely invariable; the second meaning a function which may vary, but which does not vary in the processes required by a given equation. This we propose to call the invariable function of that equation, or its invariable.

Thus, in a common differential equation, which is supposed to be true of y and x when x passes through all stages of magnitude whatsoever, the only invariable is an absolute invariable, or a common constant. But in an equation of differences, in which x only passes from one whole number to another, the invariable function is any one which remains unaltered by changing x from one whole number to another. Thus [INTEGRATION, FINITE], instead of saying that the solution of $\Delta y = x + 1$ is $y = \frac{1}{2}(x^2 + x) + \mathrm{C}$, where C is a constant, we may allow C to be any function of x, which is unaltered by changing x from one whole number to another. Such a function is $\phi(\cos. 2\pi x)$, so that the solution is $\frac{1}{2}(x^2+x)+\phi(\cos. 2\pi x)$, and the last term is the invariable of the equation.

Again, suppose it required to solve the functional equation $\phi(x^2) = 2\phi x$. One solution of this is $\phi x = c \log. x$, where c is any absolute constant. But the equation is solved if c be a function of x, provided it be one which does not change when x is changed into x^2. Such a function is

$$\cos. \left\{ 2\pi \frac{\log. \log. x}{\log. 2} \right\} \text{ or any function of it,}$$

$$\text{or } \phi x = \text{any function of } \cos. \left\{ 2\pi \frac{\log. \log x}{\log 2} \right\} \times \log x.$$

General methods of finding invariable functions, as far as they have yet been given, will be found in the 'Encyclopædia Metropolitana,' article 'Calculus of Functions.'

INVENTION (in the Fine Arts). This term, when used in the language of art, has a different signification from what it usually bears in common language. It does not mean *discovery*, but combines *conception*, or the peculiar way in which an artist's mind takes cognisance of a subject to be represented, with the *mode of treatment*, or choice of objects and manner of disposing them best adapted for producing a desired effect. Thus, in painting and sculpture, it is the faculty by which the most perfect mode of illustration, by form or by colour, is suggested to the artist, and by which the mind of the spectator is led to comprehend the truth, the intention, and the whole purpose of the work before him. But so distinct is it at the same time from perfect execution, that it is often found to exist independently of excellence in that particular, some of the finest inventions in art being manifestly defective in technical requirements.

It is hardly necessary to enter into the question whether the power of invention be a primary and original law of the mind, or whether the effect of cultivation. But admitting invention to be a gift of nature, and not reducible to rule, nor to be taught by any regular process, it still may be improved by study. Whatever natural disposition or original capacity may exist—and it will not, we suppose, be denied that some minds are more bountifully endowed than others—every power short of *creation* must have groundwork and foundation *on* which and *out of* which to exercise itself; and even the inventive faculty, which seems to approach nearest to creation, depends upon knowledge, by whatever means acquired, for materials with which to develope and declare itself.

Raffaelle, by the wonderful ability which he has shown in choosing subjects in which the greatest quantity of matter or incident could be introduced, and then in representing them at the most critical moment for illustration, in combining all the most striking and affecting circumstances, and filling the spectator's mind with the whole story, by bringing before him, as it were, the past, the present, and even suggesting that which is to follow, may justly be considered the greatest master in invention. He was gifted, if any man ever was, with the fullest portion of natural and inherent genius, but he attained his eminence by the most persevering course of exercise and observation, as the necessary and only means through which the inventive faculty could be manifested. He studied nature diligently and profoundly in all her varieties of beauty and expression. Nothing seems to have escaped him; everything that offered itself out of her great storehouse was treasured as serviceable to his art, and he acquired such an accumulation of materials, to serve as handmaids to his invention, that whatever subject came before him found him prepared, and was immediately dignified with all the expression, truth, propriety, and completeness, if we may use the word, that it was capable of receiving. Raffaelle never reached the perfect beauty and character almost superhuman which appear in the finest works of the Greeks, nor, in colour, the magic and brilliancy and breadth of Titian, another master-spirit; yet, in the largest and most comprehensive sense of the quality we have been describing, he stands (perhaps with one mighty exception) without an equal or a rival.

The examples which may be most satisfactorily adduced in illustration of invention in the fine arts, both for their excellence and for the facility of reference, as we are so fortunate as to possess them in this country, are the Cartoons of Raffaelle preserved at Hampton Court. Of these the 'Paul preaching at Athens,' 'The Sacrifice at Lystra,' and 'The Death of Ananias,' may be selected as the most remarkable for the quality we have been considering. [CARTOONS.]

Though in a totally different style, the frescoes of Michel Angelo, in the Sistine Chapel at Rome, may be equally quoted as triumphs of invention. The comprehensiveness of his scheme of illustration, and the greatness and energetic character of his design and composition, render this one of the finest monuments that art has to boast. In viewing the magnificent works of Michel Angelo in this chapel, and of Raffaelle in the loggie and stanze of the same palace (the Vatican), the spectator has a series of examples of as wonderful efforts of inventive genius in historical design as it seems possible to produce.

It should be observed here that invention is quite independent of the *class* of design; its force and power may be displayed in every part of the art, and in subjects of inferior grade, or even in the mode of treating colour, light, and shade. Rembrandt, to proceed with further illustration, is one of those who displayed very high powers of invention; "a genius," Fuseli truly says, "of the first class in whatever relates not to form;" and he justly eulogises his "powers of nature," and "the grandeur, pathos, and simplicity of his composition." Thus also, though the quality of his art was not of the highest class, the merit of invention is pre-eminently due to our own Hogarth. Turner, again, in a branch of art which by some is supposed to afford little scope for this faculty, has shown rare affluence of invention, based on close study of natural phenomena, and great imaginative and analytical power.

We have referred only to a very few out of the numerous artists whose works are worthy of attention as examples of invention; and have confined ourselves to some of the leading painters, though we might easily multiply them from productions in the sister art. Enough however has been said to point out the nature and value of that high quality in design, and to enable the intelligent observer to recognise and appreciate it when he meets it in the productions of artists, and discriminate between the efforts of elevated and original minds and the commonplace performances of mere mechanical imitators.

INVENTION and DISCOVERY. The rights of individuals, as to the honour due to the origination of new views, processes, or methods, are matters of constant discussion in the history of letters and science. It is strange that the subject should never have been generally treated: and in default of better, we intend to put together some rude materials for consideration, which may perhaps help the young reader of the history of science (from which our examples will mostly be drawn) in forming his opinion of the controversies which there abound.

Invention and discovery are, for our present purpose, synonymous terms: in older English, they were always so; thus, Locke talks of the *invention* of sciences. As commonly used, the first word signifies the formation of something which would not necessarily have existed, but for the invention; the second means the finding out that which always did exist, and would have existed whether the discovery had been made or not. We all perfectly see the error in the assertion, set down for correction in the English exercise-books, that "Galileo *discovered* the telescope, and Harvey *invented* the circulation of the blood;" and also the propriety of the assignment of words made by Macaulay, when he says that the terms in which Machiavelli is usually described would seem to import that he was "the discoverer of ambition and revenge, the original inventor of perjury." We can imagine the possibility of a telescope having never been framed, or a false oath having never been sworn; but so long as man exists his blood will circulate, and feelings of ambition and revenge will spring up in his mind. The words have some analogy with those of problem and theorem in geometry: and particularly in this, that invention must be ultimately a suggestion of discovery. The inventor of modern ink, which till his time had never existed, discovered that a mixture of galls and sulphate of iron would produce a durable dark fluid: his invention consisted in the application of his discovery to the art of writing. In this manner it may be asserted by some [BACON, ROGER, in BIOG. DIV.] that Roger Bacon discovered the telescope. There must be a discovery preceding every invention; but it does not follow that every discovery leads to invention. But yet there are some cases in which the preceding definitions fail to describe the actual use of words: for example, bichromate of potash was never found in nature, never discovered; its elements were compounded in the laboratory by its inventor. But the chemists would not call this an invention, nor anything but a discovery; we should recommend them to draw the distinction, as useful to the memory in relation to the history of their science.

There is in the words discovery and invention a tempting resemblance, often just and often fallacious, to those of theory and practice. But in fact each of the things must be subdivided into theoretical and practical. The effect of the non-spherical form of the earth upon the moon's motion was discovered theoretically; the variation and the evection were discovered practically. As to inventions, we call Davy's safety lamp a theoretical invention: for the question given was how to overcome a certain danger, generally; and it was not even assumed that a lamp was to be constructed. But the common story of the boy who saved his labour by tying a string from the valve he was employed to open and shut to a part of the machinery which moved in such a manner as to do it for him, is, if true, a record of a practical invention. Still there is truth in this, that practical men, properly so called [THEORY AND PRACTICE], have invented oftener than they have discovered; and that theoretical men have discovered more often than they have invented.

It is no wonder that the early history of discovery should be confused and uncertain: the loss of documents, which operates on all our first knowledge of antiquity, is a sufficient explanation. Nor is it surprising that first writers should be persons of unsettled claims; that in the case of Euclid, for example, we should not be so well able to say where his discoveries began as where they ended. But it does seem strange that in matters of our own day, or of that immediately preceding, it should be a question to whom a right of discovery should belong, when the only tangible matter is a book, to the date of the publication of which there is every possible attestation.

There is one most important preliminary consideration, which will, in the minds of those who for the first time give it due attention, change the face of the whole question. When the period arrives at which a discovery becomes possible, there are many courses which lead to it, and many ships sailing on each of these courses. The analogy may be carried further. When a new island is discovered in or near a frequented track, so soon as a ship of some one country casts anchor in a port and takes possession, it may be afterwards found in some logs that something like land had been suspected before, in others that land birds had been seen, in others that the colour of the water was noted, in others that an alteration of the current was observed, and so on, all near the same point, and any one of which might have led to the discovery, if the hint had been followed. It is the same in matters of science, to an extent which will not be easily credited by those who are unacquainted with its history. And this greatly enhances the merit of most original researches. It is much to the credit of Newton that Huyghens had gone so far as to determine the conditions of circular motion, that Grimaldi had noted the effect of the prism on light, that Fermat and Cavalieri had all but discovered the method of fluxions. The character of accidental good fortune disappears when we see that the progress of knowledge seems to bring new results within the possible reach of many, but within the actual grasp only of one. Is there then nothing accidental in discovery and invention? We answer that there is something, but that the accidents which *might* produce discovery are happening to all, and frequently; while the accidents which *do* produce it happen to those only who are ready to take advantage of them. But this, it may be said, is reasoning in a circle; for if we are asked how we distinguish the person who is ready to take advantage from the one who is not, we have only the discovery to point to. We reply, that it generally happens that the persons who can thus fix a casualty, are also those who give evidence of successful research in cases where fortune shows no special favour. It was by a mere accident that Mr. Baily [FLAMSTEED; BAILY; in BIOG. DIV.] bought a house opposite to the possessor of a large bundle of Flamsteed's letters, and nothing more that the fact of their existence came to his ears. Many perhaps had seen them, and either taken it for granted that the contents were all in print, or been unable to judge of their value. But the life of Flamsteed is not the only evidence of Mr. Baily's success in a point of astronomical history: there was no accident about the editorship of the old catalogues. It is said to have been by a casual effect of sun-light at a window that Malus discovered the polarisation of reflected light; but then Malus was a profound optical investigator. It is our conviction that no accidents are valid except those which happen to the proper men at the right times; and that there are usually other means of showing this besides the success of the accidents themselves.

Before we can examine the title to a discovery, it must first be settled what the discovery is: and this is frequently the greatest difficulty. The case of the steam-engine is constantly under discussion; and the principal point at issue is, what is the steam-engine. Heron of Alexandria certainly produced rotatory motion by steam, and with sufficient funds, could have ground all the corn in Egypt by his method. If we assign the merit to the person who contrived such an economy of fuel as to place the use of steam on something like its present footing of convenience, it then becomes a doubt whether any except Watt has a claim. M. Arago remarks on this subject, that a watchmaker would be struck dumb by the question, who invented a watch? The thing as it now exists is not the invention of any one person. So long as there is any national feeling in the discussion, one or another definition will be proposed, constructed to suit the advocacy of one or another claim. We have not here to settle the cases which we cite; it is enough that they illustrate our point.

It may happen that in a complicated instrument or method, the perfecting of which extends over a long period, there is some one distinguishing characteristic the introduction of which marks the main epoch of the invention. In the case of the watch, for instance, if we ask for the distinctive definition of the term, we find that it is not merely an instrument for measuring time, which would include the clepsydra. nor an application of wheel-work for that purpose, which would include the clock; but it is the use of a spring for the regulator in which consists the distinction between a watch and other horologes. In a similar manner we look upon the additions made by Vieta to the mechanism of algebra as constituting the main groundwork of what now bears the name. But it would be exceedingly wrong to say that Hooke invented a watch, or that Vieta invented algebra: things done before and after both essentially belong to the ideas we mean to convey by the words. But it is not an uncommon practice of writers to strip a word of all its accessories, and to attribute (justly enough perhaps) the invention so cut down to some one person, and then to clothe the word with all its most modern associations, and the favoured inventor with all the glory which ought to be divided among many. When the steam engine is reduced to a tea-kettle, or at most to a pump, it is Avery, or De Caus, or Worcester, or Newcomen, or Papin, &c., &c., who invented it, according to the country or the fancy of the writer; but when once the claim is established, the tea-kettle throws out a condenser, and the pump runs along the railroad at sixty miles an hour.

The common sense of the law requires that the applicant for a patent should make a distinct specification, not merely of what he intends to construct, but of that particular part of the contrivance which he claims as his own; and here a claim upon anything old, or an omission of anything new, vitiates the patent. [PATENT.] The cases which have occurred under this law would be good study for those who write on discovery.

It may indeed happen that the amount of claim may be materially augmented by the view which the discoverer takes of his own title. Columbus inferred, on true principles, the possibility of crossing the Atlantic, spent the energies of a life in procuring the means of making a trial, and is therefore properly and truly the discoverer of all the new world: the Northmen who had visited it long before did not promulgate their discovery, and it might as well be given to the aboriginal inhabitants of the continent itself as to them. It does not depreciate the merit of Columbus that he could not but suppose he should reach India or China: these were the certainties at which he aimed, and which he would have reached had he not been stopped by the intermediate continent which ought to bear his name. Had Heron, when he first announced and executed his revolving boiler, been able to point out that it was a method of producing force from fuel, which might supply the place of human labour—that all which remained was adaptation—and that skill in the use of this new kind of force would make it a substitute for the strength of men and beasts—it would have been difficult to have denied him the title of the discoverer of the steam-engine, and the inventor of the first step.

Among the consequences of attempting to describe discoveries under too general terms, is this, that both things and persons are allowed to clash unnecessarily. It is not always, to be sure, that this goes such a length as procuring for Dalton's atomic theory the character of being a republication of the notions adopted by Epicurus from his predecessors; if it did there would be less harm: there are many theories between which mischievous confusion is more easily brought about than between those of the philosophers of Athens and of Manchester. The nomenclature of science is perplexed by phrases of no precision—as that Newton discovered gravitation, instead of a true explanation of the heavenly motions by means of *universal* gravitation—that he first advanced the true theory of astronomy, which he did in one sense, and Copernicus in another; whence the provinces of the two are frequently confounded. It must also be noticed that a mere opinion, the result of choice between several, one or other of which must have been taken, is confounded with the same opinion advanced and supported by reasons. Thus Philolaus and Aristarchus asserted the motion of the earth, and Copernicus is said to have only revived their opinion. The difference between the two cases lies in this, that the ancient philosophers merely asserted their belief, the modern one made his hypothesis the means of accounting for all the known motions of the heavens, diurnal, annual. and precessional.

The specification, to borrow a term, having been agreed upon, the next question is, what constitutes a claim to discovery? The answer is priority of publication. If, as has often happened, two persons should discover the same thing about the same time, the one who first publishes is universally recognised as the discoverer; for 'discoverer' either implies priority, or is an abbreviation of the words 'first discoverer.' Of course if a fraud can be proved, if it can be satisfactorily shown that the first publisher stole his matter from another, he would not be allowed the advantage of his wrong: but the onus of proving the fraud lies entirely upon the assertor of it, and, until the evidence and verdict arrive, the first publisher is in possession. The reasons for this rule are not altogether those which exist for the rule in law. The objects of the latter are the protection of private rights and public peace; or rather the assignment of private rights in such a manner, as best, in the long run, to promote the welfare of the community, and particularly its peace, without any great shock to the natural feelings of equity. It is not difficult to conceive a class of cases in which men would gladly give up a small per centage of decisions consonant to natural justice, or what is so called, for the sake of a rule which would present decided advantages as a rule, in the imperfect state of private morality. But the object of the scientific historian is truth for its own sake; he has nothing to do with conventions made for the sake of peace.

This rule, that first publication gives the right, until the contrary is proved, is adopted for the sake of its own probability as a starting point. Select at hazard the name of a result, and of its first announcer; no doubt will exist in the mind of any one, used to the history of science, that it is at least fifty to one the name of the real discoverer is thus given. But if it be *the fact* that the discovery was made at an earlier period, and if that fact can be established, the history of the human mind must not be falsified by adherence to a rule. If, for example, it could be made out, from internal evidence, that Archimedes must have had an algebra and a differential calculus, which deference to the notions of his time prevented him from publishing, it would never do to let the formal claims of Leibnitz and Newton prevent the allowance of that of Archimedes: for then would result the suppression of the actual fact, which, if true, would be of great consequence, namely, that the Greek mathematics were powerful enough to lead their best minds to the discoveries of modern times. We insist upon this because we have observed a considerable tendency in writers of history to establish a rule on legal grounds of peace and convenience. There is also a confusion between two distinct things; the claims of history, and the claims of the individual: the former demands true facts, the latter just appreciation of his merit. By a perversity of the human mind, Newton and Leibnitz would lose fame to-morrow, more or less,—that is, more with some and less with others —if an undoubted manuscript of Archimedes were to turn up, showing that he possessed a formal differential calculus. We are apt to assign praise to mere priority, independently of originality, and to withdraw it on failure of priority. But it is forgotten that the merit of priority only lies in this, that the earlier an invention or discovery is made the ruder are the methods and instruments, and the fewer the hints to which it is due. For example, D'Alembert re-invented Taylor's theorem [TAYLOR, in BIOG. DIV.] in, or shortly before, 1754. He has all the merit due to the discovery, as in 1754. But could it now be proved that Taylor's works, &c., were recent forgeries, so that D'Alembert should stand as the original inventor, it would be impossible to put him in Taylor's place; the differential calculus was in two very different states in 1716 and in 1754.

There is also an injurious tendency to stand by the fixed rule as a thing of good consequences, in the way of punishment or stimulus: and certainly there is no denying that if it were but right to substitute in history the thing which is not for the thing which is, there are advantages arising from the adoption of the rigid rule of first publication. Tartaglia [TARTAGLIA, in BIOG. DIV.] suppressed his method for cubic equations from a selfish motive: Cardan, to whom he had communicated it under promise of secrecy, published it, with a sufficient acknowledgment; nevertheless the rule always goes by Cardan's name. There is little to regret here: Tartaglia was willing, simply that he might be able to puzzle his contemporaries, to retard the progress of algebra; it is not certain that he ever would have published his discoveries. The public has rewarded the individual to whom they were indebted for knowledge by affixing his name to the rules he announced. If it were understood that the name attached to any scientific result was always that of the first publisher, saving all the rights of history over the truth of the discovery, this and similar acts of nomenclature might be a satisfactory use of the *norma loquendi*. It has sometimes happened that individuals have deposited sealed packets with public scientific bodies, to preserve their rights in the event of any one else arriving at results which they wished to avoid making public until they had followed them out to their remote conclusions. This practice is one which would not prevent the name of any other person from being attached to the contents of the packet, if he came independently by the same results, and published them before the packet was opened, though unquestionably the packet would prove the privity of the depositor.

The next question is, what constitutes a sufficient publication. And here the answer is, that the only mode which can give the discoverer no further duty in the matter, is the press. If any one should prefer written correspondence, public lectures, or oral conversation, it must be at his own risk. A printed book, pamphlet, magazine, or newspaper which any one who likes may buy, is a record of the court of history from the day of its appearance: but any other mode of communication, which is of its own nature not addressed to the public at large, must be put in and proved before it can be available. A communication to a scientific body, for example, is only so much better than a letter to a friend, as it is more public and more easily proved: but unless it be published in the transactions of that body, in which case it ranks with a book from the date of publication, it will require subsequent establishment. There is, however, always a difficulty with regard to such communications, particularly when the transactions of the academy in question do not appear till some time after the reading of the memoir. It is impossible to know what an author has added as the paper went through the press: that is, if a contest of dates should arise, it will always be necessary to assume the date of publication, unless some proof can be given that the memoir as published is, in the matter under dispute, the same as that which was originally communicated. It has happened before now, that a communication presented has been almost entirely remodelled before it was printed. We have little doubt that, in course of time, bodies which publish transactions will find it necessary to require that authors should either print their communications as presented, or date such additions as they feel desirous of making. Since these remarks were first written, some of the scientific societies have enforced attention to these points.

The most remarkable question of publication that ever arose was that relative to the invention of fluxions. [FLUXIONS; COMMERCIUM EPISTOLICUM.] There never was a case in which it was more necessary to consider the rights of history, and not to judge by any fixed rule. Newton, unquestionably the first inventor, made no publication whatever at the time: an anagram, or transposed sentence, cannot be looked upon in any other light than as a sealed packet. Leibnitz has accordingly the full merit of an inventor, and priority of publication. Newton has given proof that he could have published it, if he had chosen. He is the first inventor; Leibnitz is the benefactor of the world.

It frequently happens, as before observed, that independent discoveries take place about the same time: there is no doubt that such is the fact. When the publications take place very nearly at the same time, particularly when they are in different countries, it is easy enough to admit the real independence of the two. If the same thing should appear in the notices of the Royal Society and the Comptes Rendus of the French Institute within a few weeks of each other, the presumption is strong in favour of neither writer having had a communication, directly or indirectly, from the other: and this presumption must be rebutted by any one who desires to prove plagiarism. But as the interval of time becomes greater, the presumption, so far as it is derived from time only, is weakened. In such a case, the internal evidence of the writings themselves must be carefully looked at. There is usually a very great difference between the modes in which different investigators arrive at, and even in which they state, the same conclusions: those who would do a dishonest thing might know this as well as others, and might endeavour to counterfeit originality. To detect the base metal is not always easy: to prove its baseness is next to impossible. But it mostly happens that really independent investigators carry their results to different lengths; one will go further in one part of the subject, another in another.

As may be supposed, the most disputed cases are national ones; including in that term the schisms of different classes in the same country, as the scientific feuds of universities, of literary societies, &c. And between people of different countries and governments, the question arises in two distinct ways, not only as to the definition of the discovery itself, and the priority of publication, but as to the country to which the discoverer is to be said to belong. And here there seems to us to be a necessity for a distinction which is rarely made, and no wonder; national pride is the mortal enemy of discriminative argument. All people like to believe that their race is gifted by nature with talent, and that their public policy is calculated to draw it out. For proof of this they appeal to their great writers and thinkers, among whom they include all whom they have drawn into their country, and all whom they have driven out. Now it is clear that the eminent men who have been induced to settle in a country not their own, may be a credit to the institutions, but can be none to the race, of their adopted country; while those who are driven away may do honour to the race but not to the institutions of the land from which they are exiled. Take the cases for instance of Lagrange and De Moivre. Lagrange, who, of many offers made to him when he left Prussia, preferred that of the king of France, resided in that country from 1787 till his death in 1813, was exempted from the expulsion of foreigners ordered by Robespierre, and received, during all governments from the old monarchy to the empire, every possible honour and aid,—is a greater credit to French institutions and feelings than if he had been born in their country. But so far as blood is concerned, he is almost wholly Italian, having been born, and established his first reputation, at Turin: his mother tongue was Italian, and his first work was published in Italian. It is said, we do not know on what authority, that his great grandfather was a Frenchman, which may entitle France to claim the eighth part of him. De Moivre, on the other hand, born of French parents and educated in France, was driven from his country by religious fanaticism, and none of his works were published either in France or in French. Whatever credit his talents may do to his race, he is the disgrace of their institutions, as to the time in which he lived. Not that he received such encouragement here as would entitle us to say that the honour lost by France was wholly gained by England. While picking up a scanty living by private teaching, the only way in which he could find time to read the Principia was by tearing it leaf from leaf, and carrying a leaf in his pocket to look at while walking from one pupil to another, or at any other chance interval.

There is much absurdity in the mode by which national prowess in matters of discovery is tested. A few of the very first names are made the only subjects of comparison. There is some presumption, certainly, that the great names are the best of many, and that the plants are most numerous where the largest plants are found. But this presumption must not be urged when an attentive consideration will settle the question without it. Archimedes was the greatest of the Greek mathematicians; but Sicily was not therefore the most celebrated in science of all the countries in which Greece had colonised. So far from it, that when in the sixteenth century Maurolico lived and wrote, the following epigram was made upon him—

> Te quoque Zancla tulit, Maurolyce, ne sit in uno
> Clara Syracosio Sicelis ora sene.

The most difficult question of all is undoubtedly what degree of merit belongs to a discovery, and the settlement of the question where in the list it places its author. The public in general judges by utility; whereas it is notorious that many discoveries show more power of mind than others of much greater value to the world. The rule of utility is a good one for mankind in general; but it must be taken with modification by the historian of science. Who has most benefited his species, and who has shown himself most above his species in intellect, are two different questions. The merit of the inventor, and his genius, are not comparable quantities. The merit is determined by the study, the personal risk or inconvenience which it was requisite to undergo, the patience and perseverance which must have been shown, and the goodness of the motive which appears to have actuated. The genius is the greater the less the pain and labour, and is wholly independent of moral considerations. A patient schoolboy who multiplies one number by another with time and care, has more merit than the wonderful youths who have sometimes appeared, and who can do it in their heads; but the first has far less mental power, in this one line, than the second. All these things are plain on the first statement; but they are far from receiving due attention, and will so remain until the history of discovery is written without too much deference to popular reputation.

We may mention, as a thing to be guarded against, the disposition to depreciate a discovery because it is not something more than it pretends to be, which is frequently combined with a wish to judge of its merit by an arbitrary *à priori* standard of what it ought to have been. Sturm's theorem is a very pretty instance. Before it appeared, a purely theoretical and strictly certain method was eagerly sought after, and any such, however difficult, would have been held a great gain. The object is at last attained, but in a manner which is troublesome to use. To look at the way in which some writers now mention it, one would suppose they had entirely forgotten how many investigators of the first order had given up the subject without producing any method at all.

Since the preceding article was published, many confirmations have arisen of our assertion that for the most part discoveries are made by more than one person when the right time arrives. The eighth satellite of Saturn was discovered on one and the same day in England and America; and several of the smaller planets, those specks of which there are hundreds, perhaps thousands, in our system, have been twice announced within a few days by observers of whom the second was ignorant of the success of his predecessor. But the most remarkable case of simultaneous investigation which ever occurred was the solution of the inverse problem of gravitation by Leverrier and Adams, which resulted in the discovery of NEPTUNE by Galle, at Berlin, on information furnished by Leverrier. It is not our intention to enter on this celebrated case: we shall only make a remark on the discussion which it produced. [ASTEROIDS.]

It soon became apparent that in the scientific world, both of England and France, the word *publication* retains its old meaning, though in common language it now means circulation by help of the press. To publish is, in science as in law, to make known to others, no matter how. Some little disposition was shown by a few to confound publication, the genus, with printing, the species; but without producing any general assent. And a reference was made to *Waring's rule*, a phrase of which we gave no explanation in the preceding article. We proceed to supply this omission, because we have since heard it cited as the rule to which men of science appeal in matters of priority. They follow, it is said, the rule laid down by Waring, that the first publisher is to be held the discoverer: and it is frequently insisted that this word publication is used in the modern and restricted sense.

Waring ('Medit. Analyt.' pref. p. ii, 1776) speaking about a claim of John Bernoulli to something which had been shown both by Newton and Leibnitz, as having been found by himself before he had seen their writings, speaks as follows:—

> "Sed nemo potest esse testis in suas partes, is mihi semper dicendus est inventor, qui primus evulgavit, vel saltem cum amicis communicavit, vix enim inveniatur aliquis, dignus mathematici nomine, qui de suo ingenio multa scriptorum priorum reperta haud detexit."

That is to say, Waring held the inventor to be the first who *evulgates*—tells to all, no matter how—or at least tells to his own friends. And in truth even these conditions are not so much Waring's rule, as Waring's examples of the way in which discovery may be proved under his rule. That rule is implied in his opening dictum, that no man may be his own witness; that is, evidence distinct from his own, and sufficient without it, must be produced. And this is common sense. A man must prove that he is the discoverer: it is not enough to prove that he is either the discoverer, or a self-deceiver or a rogue.

For ourselves, we admit no right in any one to lay down a rule: or if we should be pressed to state some rule, we can only say that we hold by the rule in Chrononhotonthologos:—

> "Go! call a coach! and let a coach be called!
> And *let the man who calleth be the caller!*"

Let the man who discovers be held the discoverer; and let evidence settle who that man is: and let evidence be that which makes knowing and reflecting men believe; we know no other definition. And if knowing and reflecting men be seriously divided in opinion, let it be held undecided who is the discoverer. The reason of this rule is that it always has been the rule, is, and always will be the rule. The attempt to lay down a law of assignment of discovery has not succeeded: the law is quoted with respect until a dispute arises, and then *all* the facts of the case are discussed, which is tantamount to a downright refusal to obey the law. For it is to be observed that the rule of first publication is of no import except in its negative or prohibitory character. That the first publisher, no other fact except first publication being on the record, shall be held the discoverer, needs no reduction to rule: it is mere conclusion of course. The asserted rule means that first publication shall exclude from the discussion all other considerations of fact, or shall be conclusive against them, if introduced. This it never has been, and never will be.

INVENTORY. [EXECUTOR.]

INVERSE, INVERSION. Any two operations of algebra are said to be inverse when one of them undoes, so to speak, the effect of the other; so that if both be successively performed upon the same quantity, the result is that quantity itself. For instance, the operations implied in $1+x^2$ and $\surd(x-1)$ are inverse to one another; for

$$1+\left\{\sqrt{x-1}\right\}^2=x, \qquad \sqrt{(1+x^2-1)}=x.$$

We need do no more than name addition and subtraction, multiplication and division, raising of powers and extraction of roots, as pairs of inverse operations.

The operation of inversion is the solution of an equation and *vice versâ*. Let it be required to find the operation inverse to ϕx. Assume $\phi x=y$, and find x in terms of y; say $x=\psi y$, then $\phi(\psi y)=y$, or ϕ and ψ are inverse operations. Thus if $x^2-2x=y, x=1\pm\sqrt{y+1}$, and either of the two, $1+\sqrt{x+1}$, or $1-\sqrt{x+1}$, is inverse to x^2-2x.

It thus appears that a function may have more than one inverse function, and there are functions which have an infinite number; but there is a distinction by which one may be separated from all the rest. Let the Greek letters in this article be all functional symbols, or marks of operations to be performed, and let them come before the subject of operation, the quantity x, or y, &c., in the order in which they are to be performed. Thus $\alpha\phi x$ denotes the result of performing the operation ϕ upon x, and then the operation α upon ϕx. Now let $\phi x=z$ give $x=\psi z$, where ϕx is an unambiguous operation, and ψz is, generally speaking, ambiguous, or presenting several different forms. Then ϕ and ψ are inverse operations, and $\phi\psi z=z$, and we might suppose at first that $x=\psi\phi x$; that is to say, we might imagine that ψ destroys ϕ as well as that ϕ destroys ψ. But since ψ is ambiguous, it may be that only one or more of the forms of ψ will satisfy $x=\psi\phi x$, and not all; and that this will be the case with one is obvious, while we can show that it cannot happen with more than one. For though the same operation, performed on different functions, may produce the same function, yet different operations, performed on the same function, must produce different functions. If then α and β be different forms of ψ, we have $\phi\alpha x=x$ and $\phi\beta x=x$; but we cannot have both $\alpha\phi x=x$ and $\beta\phi x=x$, where α and β are different, ϕx having absolutely the same form and value in both equations.

From all the inverses of a function ϕx, then, we separate that one, αx, which gives both $\phi\alpha x=x$ and $\alpha\phi x=x$, and call it the *convertible* inverse. Its symbol is ϕ^{-1}, so that $\phi^{-1}x$ means that operation which satisfies both the equations $\phi\phi^{-1}x=x$ and $\phi^{-1}\phi x=x$. [EXPONENT.] In the preceding example $1+\surd(x+1)$ is the convertible inverse of x^2-2x: for $1+\surd(x^2-2x+1)=1+x-1=x$. But $1-\sqrt{x^2-2x+1}$ gives $1-(x-1)$ or $2-x$; and we call $1-\surd(x+1)$ an inconvertible inverse.

Every function which has more than one inverse is not only a function of x, but the same function of other functions of x. Let αx be an inconvertible inverse of x; then $\alpha\phi x$ is not x, let it be ωx. Then $\phi\alpha x$ being x, $\phi\alpha\phi x$ is ϕx, or $\phi\omega x$ is ϕx, so that ϕx is the same function of ωx which it is of x. Thus in the preceding example x^2-2x is the same function of $2-x$ which it is of x; or

$$x^2-2x=(2-x)^2-2(2-x).$$

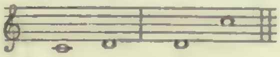
We have then this theorem: every function has as many different forms as inverses, and all these forms can be made by writing different functions of x instead of x in the original function; and each inverse of the function is the convertible inverse to one of its forms, and an inconvertible inverse to all the rest. Thus $1-\surd(x+1)$, which is an inconvertible inverse to x^2-2x, is the convertible inverse of $(2-x)^2-2(2-x)$: for

$$1-\surd\left((2-x)^2-2(2-x)+1\right)=1-(2-x-1)=x.$$

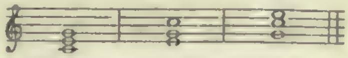
The way to make the convertible inverse of a given function find all the rest is as follows. Find the solutions of the equation $\phi\,\omega\,x=\phi\,x$, and let them be $\omega_1\,x, \omega_2\,x$, &c. Then $\phi^{-1}x$ being the convertible inverse of $\phi\,x$, the remaining inverses are $\omega_1\,\phi^{-1}x$, $\omega_2\,\phi^{-1}x$, &c. Thus in the preceding example $\phi^{-1}x$ being the convertible inverse, the other is $2-\phi^{-1}x$. [PERIODIC FUNCTIONS.] There is a remarkable class of functions, each of which is its own inverse, such as $1-x$, $\frac{1}{x}$, $\sqrt{(1-x^2)}$, &c. Now if $\phi\,x=\phi^{-1}x$ we have $\phi\,\phi\,x=x$, and these functions will be considered, in the article just cited, as periodic functions of the second order.

The equation $\phi\,\phi^{-1}x=x$ being understood, suppose that between the first and second operations we interpose the operation α, so that we have $\phi\,\alpha\,\phi^{-1}x$. This is no longer equal to x, but it is a function, the properties of which are closely connected with those of $\alpha\,x$. For instance, if $\alpha\,x$ and $\beta\,x$ be inverse to each other, then $\phi\,\alpha\,\phi^{-1}x$ and $\phi\,\beta\,\phi^{-1}x$ are also inverse to each other: for $\alpha\,\beta\,x=x$ and $\phi\,\alpha\,\phi^{-1}\left(\phi\,\beta\,\phi^{-1}\right)x$ is $\phi\,\alpha\,\phi^{-1}\,\phi\,\beta\,\phi^{-1}x$, or $\phi\,\alpha\,\beta\,\phi^{-1}x$, or $\phi\,\phi^{-1}x$, or x. Thus knowing $x+1$ and $x-1$ to be inverse functions, we know immediately that $\log(\epsilon^x+1)$ and $\log(\epsilon^x-1)$ are inverse functions; and also $\sqrt{(x^2+1)}$ and $\sqrt{(x^2-1)}$. For more detail on this subject see the article 'Calculus of Functions,' in the 'Encyclopædia Metropolitana.'

INVERSION, in Music, is a change in the relative position of two sounds, or of the several notes of a chord. Thus, C D, an interval of a 2nd, becomes by inversion (D C) a 7th. Example,—



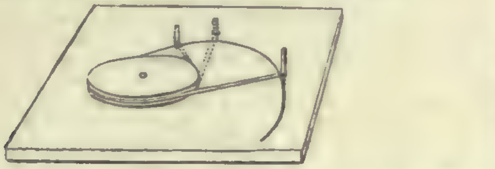
And C E G, the notes of the triad, or perfect chord, by inversion become the chord of the 6th (E G C), or of the $\frac{6}{4}$th (G C E). Example,—



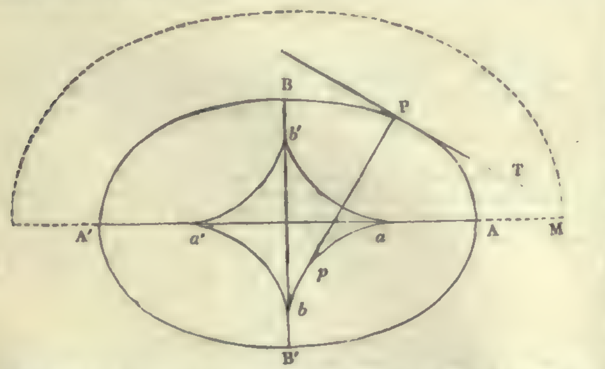
For other musical inversions, see CANON and FUGUE.

INVESTITURE. [FEUDAL SYSTEM.]

INVOLUTE AND EVOLUTE (the curve unrolled and the curve from which it is unrolled), a name given to two curves so formed and placed, that supposing the second to be cut out from solid matter, the first can be formed by fastening one end of a thread upon a point in the second, attaching a pencil to the other end, and moving the pencil so that the thread may either gradually enwrap or be unwrapped from the curve to which it is fastened. Thus the pencil in the diagram is describing the involute of a circle, or the curve of which the circle is the evolute. But the evolute of a circle is evidently a point.

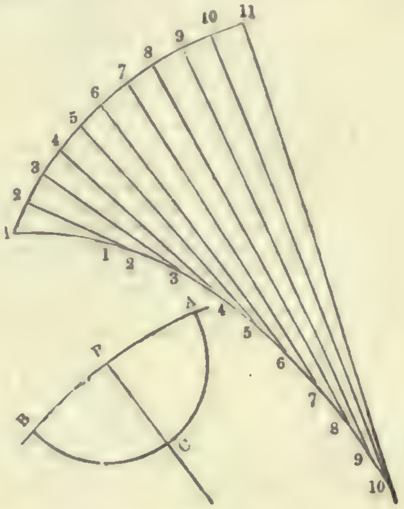


The following figure represents an ellipse with its evolute. If the thread be fastened at b, wrapped over $b\ a$, and continued to A, it will, as it unwraps from $a\ b$, describe the arc A B; and B A′ while it wraps over $b\ a'$. If fastened in a similar manner at b', it will by the same process describe A B′A′.



If the line p P be drawn tangent to the evolute at p, it is one of the positions of the thread, and P T, the tangent of the involute at P, is perpendicular to p P. Also p P is the radius of curvature of the involute at P; this is to say, no circle can pass so near the curve at P, as the one which has p for its centre and p P for its radius. [CURVATURE.] Also, any arc of the evolute is the difference of two radii of curvature of the involute: thus the arc $a p$ is the difference between a A and p P. Such are the principal geometrical connections of the two curves.

Every curve has one evolute, and an infinite number of involutes. For instance, fastening the thread at b, and continuing it to M instead of A, we may with the cheeks $a\ b$ and $b\ a'$ produce another involute from them (represented by a dotted line); and any number, however great, by varying the position of M. But none of these involutes will be ellipses, except the one from which the evolute was made; though they will all be ovals having remarkable analogies with the ellipse. The proper name for curves described from the same evolute is *parallel curves*, since they have the fundamental property of parallel lines: for they never meet, though (if they admit of it) ever so far produced; a straight line perpendicular to one is always perpendicular to the other; and the part of the perpendicular intercepted is always of the same length. When arcs of parallel curves are required to be laid down, the most commodious method of proceeding is to construct the evolute of one of the arcs approximately, as follows. On the arc draw tangents at moderately small distances, and draw perpendiculars to those tangents. The parts of the tangents cut off from each by its neighbours will together give the arc of the evolute near enough for all purposes. And it may be well to notice that it will be a sufficiently accurate method of drawing the perpendicular to the tangent at a point P, if we take a small circle whose centre is P, bisect the arc A C B in C, and join and produce P C.



The angular error thus committed is only a small portion of the angle made by the tangents at P and A.

Whenever the two arcs adjacent to a normal (or perpendicular to the tangent) of the involute are equal and similar, there is a cusp in the evolute; and the evolute generally recedes without limit as we approach a point of contrary flexure in the involute.

The mathematical method of finding the evolute is as follows. Let $y=\phi\,x$ be the equation of the involute, and let X and Y be the co-ordinates of the point on the evolute corresponding to that on the involute whose co-ordinates are x and y. Form the three equations—

$$y=\phi\,x;$$
$$X-x+\frac{dy}{dx}(Y-y)=0;$$
$$1+\left(\frac{dy}{dx}\right)^2-\frac{d^2y}{dx^2}(Y-y)=0;$$

and from them eliminate x and y. The resulting equation between X and Y is that of the evolute. But if the evolute be given, and the involute is to be determined, let $Y=f\,X$ be the equation of the former, and from this and the latter two of the preceding three equations eliminate X and Y. There will result a differential equation of the second order between y and x, among the primitives of which is the equation of the involute. But the differential equation of the involutes is one of the *singular* primitives of this equation of the second order, and the question is most easily treated in the following way. Find the differential equation of the curves which cut all the tangents of the given evolute at right angles: those curves are the involutes required.

Thus if the curve be a parabola having the equation $y=c\ x^2$, the equations for determining the evolute are—

$$y=c\,x^2;$$
$$X-x+2\,c\,x(Y-y)=0;$$
$$1+4c^2x^2-2\,c\,(Y-y)=0;$$

from which we find—

$$X=-4c^2x^3,\qquad Y=\frac{1}{2\,c}+3\,c\,x^2;$$

which give $Y=\frac{1}{2\,c}+\frac{3}{2}\left(\frac{X^2}{2\,c}\right)^{\frac{1}{3}}$.

the equation of the evolute of the parabola, which evolute therefore appears to be what is called a *semi-cubical* parabola.

For considerations similar to those which precede see CAUSTICS.

INVOLUTION and EVOLUTION (Arithmetic). Taking these words in their etymological sense, they might stand for the greater part of mathematical analysis. In their technical algebraical sense, they mean only the raising of powers, and the inverse operation, the extraction of roots. The revival however of a general process, accompanied by an improvement which makes it comparatively easy, renders it necessary to make a more extensive definition of the terms. We shall not relinquish any characteristic of the old meanings, and shall bring all corresponding processes together, by laying down the following definition :—Involution is the performance of any number of successive multiplications with the same multiplier, interrupted or not by additions or subtractions; and evolution is any method of finding out, from the result of an involution, what multiplier was employed, provided that the said method proceed by involutions. Thus to determine $2x^3+4x^2-3x+10$ by involution, we multiply 2 by x and add 4; then multiply by x and subtract 3, then multiply by x and add 10. If this give 1000, then any method of determining x which proceeds by successive involutions is evolution.

Forty years ago our only instances of evolution would have been common division, and the extraction of the square and cube roots, with references to Vieta, Harriot, Oughtred, and the older algebraists in general, for evolutionary methods of solving equations, bearing a strong likeness to such extractions. But since the publication of Mr. Horner's 'New Method of Solving Equations of all Orders,' 'Phil. Trans.,' 1819, the process which has rendered it worth while to propose the preceding extension of terms has been in the hands of mathematicians. For a more detailed account than we can here give, the reader is referred to the paper just cited, which is reprinted in the 'Ladies' Diary' for 1838, or to 'The Theory and Solution of Algebraical Equations,' by Professor Young, of Belfast (London, J. Souter, 1835).

We should begin with simple division, and the extraction of the square and cube roots, if we were writing an elementary treatise. But taking it for granted that the reader is familiar with the first two, at least, we shall proceed to describe the general process. This consists of three distinct parts, the first two of which have been long known, while the third, which contains the peculiar distinction of this method, is due to Mr. Horner.[*]

1. In the article APPROXIMATION it is shown that if a be a value of x which makes ϕx very small, then $a-(\phi a \div \phi' a)$ is a value of x which makes ϕx much smaller; so that a continued succession of approximations may be made to a value of x which makes ϕx absolutely $=0$. Here ϕx means the differential coefficient or derived function, and if

$$\phi x = Ax^n + Bx^{n-1} + Cx^{n-2} + \ldots\ldots;\ \text{then}$$
$$\phi' x = nAx^{n-1} + (n-1)Bx^{n-2} + (n-2)Cx^{n-3} + \ldots.$$

2. Meaning by a root of ϕx, any value of x which makes $\phi x=0$, it is obvious that $\phi(x+a)$ is a function which has for its roots the roots of ϕx, each diminished by a. And the substitution of $x+a$ instead of x in the preceding value of ϕx gives a well known development, of which an instance will be more to our present purpose. Let the function be

$$Ax^5 + Bx^4 + Cx^3 + Dx^2 + Ex + F \ldots. (1).$$

Write $x+a$ for x, and this becomes

$$Ax^5 + (5Aa+B)\,x^4 + (10Aa^2+4Ba+C)x^3 + (10Aa^3+6Ba^2+3Ca+D)\,x^2$$
$$+ (5Aa^4+4Ba^3+3Ca^2+2Da+E)\,x + Aa^5+Ba^4+Ca^3+Da^2+Ea+F\,;$$

which we may represent by

$$Ax^5 + \phi_4 a\,x^4 + \phi_3 a\,x^3 + \phi_2 a\,x^2 + \phi' a\,x + \phi a.$$

3. The quantities ϕa, $\phi' a$, $\phi_2 a$, &c., may be determined by a succession of involutions, each one making use of the results of the preceding. Find ϕa by involution, of which the following are the steps :—

$$\begin{array}{l}
A \\
Aa + B \\
Aa^2 + Ba + C \\
Aa^3 + Ba^2 + Ca + D \\
Aa^4 + Ba^3 + Ca^2 + Da + E \\
Aa^5 + Ba^4 + Ca^3 + Da^2 + Ea + F = \phi a
\end{array}$$

Repeat the process, using the preceding quantities, except the last and we have $\phi' a$ by the following steps :—

$$\begin{array}{l}
A \\
2Aa + B \\
3Aa^2 + 2Ba + C \\
4Aa^3 + 3Ba^2 + 2Ca + D \\
5Aa^4 + 4Ba^3 + 3Ca^2 + 2Da + E = \phi' a.
\end{array}$$

A repetition of the process, leaving out the last, gives $\phi_2 a$, as follows :—

$$\begin{array}{l}
A \\
3Aa + B \\
6Aa^2 + 3Ba + C \\
10Aa^3 + 6Ba^2 + 3Ca + D = \phi_2 a.
\end{array}$$

Repetition gives $\phi_3 a$, and finally $\phi_4 a$, as follows :—

$$\begin{array}{lcl}
A & \qquad & A \\
4Aa + B & & 5Aa + B = \phi_4 a \\
10Aa^2 + 4Ba + C = \phi_3 a & &
\end{array}$$

In numerical application the operations may be made to stand thus, where a new letter below a line stands for the sum of the two preceding; and ϕa, $\phi' a$, &c., are introduced when found.

$$\begin{array}{cccccc}
A & B & C & D & E & F \\
 & Aa & Pa & Qa & Ra & Sa \\
\cline{2-6}
 & P & Q & R & S & \phi a \\
 & Aa & Ta & Ua & Va & \\
\cline{2-5}
 & T & U & V & \phi' a & \\
 & Aa & Wa & Xa & & \\
\cline{2-4}
 & W & X & \phi_2 a & & \\
 & Aa & Ya & & & \\
\cline{2-3}
 & Y & \phi_3 a & & & \\
 & Aa & & & & \\
\cline{2-2}
A & \phi_4 a & \phi_3 a & \phi_2 a & \phi' a & \phi a
\end{array}$$

If a be of only one significant figure (as 200, 6, ·03), all the operations necessary to fill up this process can be performed in the head, and we have thus (for the method is general, though our example be only of the fifth degree) a working method of answering the following question :—Given a certain equation $\phi x=0$; required the equation $\psi x=0$, the roots of which are each less by a than those of $\phi x=0$.

If ϕa came out $=0$, we should then know that a is a root of the equation: and the method of approximating to a root is as follows :—Suppose we have an equation of which the root (unknown to us) is 26·73. By trial, or otherwise, suppose we find that 20 is the highest denomination of the root, and we thereupon find another equation, each of whose roots is less by 20 than a root of the given equation: this is done by the preceding process, and one of the new roots (but unknown) is 6·73. If we can find that the highest denomination of this root is 6, we make another reduction of all the roots, and find a new equation, one of whose roots is ·73. If we can then find ·7 to be the highest denomination, we repeat the process and find an equation one of whose roots is ·03. In finding the highest denomination of this root we find the root itself, evidenced by the ϕa of this final process being $=0$.

The first denomination of the root must be found by trial, or by some of the methods referred to in THEORY OF EQUATIONS. But the second and the remaining ones are found by comparing the results ϕa and $\phi' a$. If a be nearly a root,

$$a - \frac{\phi a}{\phi' a} \text{ or } a + \frac{-\phi a}{\phi' a}$$

is still nearer. Consequently, by dividing $-\phi a$ by $\phi' a$, we may, after the second process, be sure of finding one figure of the remaining root correct. But after the first process we may be liable to an error of a unit (to be corrected by a new trial), as in extraction of the square root.

In order to obtain $-\phi a$ and not ϕa, let the last coefficient, F, have its sign changed, and let the process in the column which contains it be always subtraction, and not addition. In the preceding type of calculation, we should then have

$$\begin{array}{rcl}
-F & & F \\
Sa & \text{instead of} & Sa \\
\cline{1-1}\cline{3-3}
\text{Subtr.}\ -\phi a & & \phi a\ \text{Add.}
\end{array}$$

In carrying on the process, the results ϕa, $\phi' a$, &c., come in a diagonal line; before taking the next step, the beginner may bring them down into one line, as in the type preceding. In our examples, asterisks or other symbols will mark results of a process.

We now apply this method to the solution of the equation—

$$x^4 + 2x^3 - x^2 - x - 631064798 = 0.$$

It will be found that a root lies between 100 and 200.

---

[*] Mr. W. G. Horner was a schoolmaster and mathematical teacher residing at Bath, and died September 29, 1837. There has been some dispute about the right to the invention, of which we shall presently speak.

1	2	−1	−1	631064798(158
...	100	10200	1019900	101989900
	102	10199	1019889	529074898 :
	100	20200	3039900	410987450
	202	30399	4059799 :	118087448 ;
	100	30200	4159950	118087448
	302	60599 :	8219749	0
	100	22600	5414950	
	402 :	83199	13634699 ;	
...	50	25100	1126232	
	452	108299	14760931	
	50	27600		
	502	135899 ;		
	50	4880		
	552	140779		
	50			
	602 ;			
...	8			
	610			

Assuming 100 as a first approximation, we find that $x^4+402x^3+60599x^2+4059799x-529074898=0$ is an equation having roots less by 100 than those of the given equation. And 529074898 contains 4059799 upwards of 130 times; but if any number of tens greater than 50 be taken, the accumulations of the next involution will give more than 5290, &c., as must be found by trial. Repeating the process, we find that $x^4+602x^3+135899x^2+13634699x-118087448=0$ is an equation all whose roots are less by 50 than those of the last. We can now depend upon 118087448 divided by 13634699 giving one figure of the root, and the quotient is between 8 and 9. Assuming 8, the first step of the third process shows that 8 is a root of the last equation, and 58 of the preceding, and 158 of the given equation.

We now give an example in which approximation is carried on. Let the equation be $x^3-6x^2+7x+4=0$, of which one root lies between 2 and 3.

1	−6	7	−4(2·414213562
	2	−8	−2
	−4	−1	−2 :
	2	−4	−1·936
	−2	−5 :	−0·064 ;
	2	0·16	−0·045079
	0 :	−4·84	−0·018921†
	0·4	0·32	−0·017963056
	0·8	−4·52 ;	−0·000957944‡
	1·2 ;	0·0121	−0·000897113
	1·21	−4·5079	−0·000060831‖
	1·22	0·0122	44853
	1·23†	−4·4957†	15978
	1·234	0·004936	13456
	1·238	−4·490764	2522
	1·242‡	0·004952	2243
	1·2422	−4·485812‡	279
	1·2424	0·000248	269
	1·2426‖	−4·485564	10
		0·000248	8
		−4·485316‖	2

The root of this equation is found to be 2·414213562, as follows. Beginning with the multiplier 2, one set of involutions brings us to the figures followed by colons, and $x^3+0x^2-5x+2=0$ is an equation on which the process is to be repeated. Dividing −2 by −5 we find that ·4 is most probably the next figure, which is verified in the next trial, since the result of involution, 1·936, is less than 2. We proceed in this way until 2·4142, containing half the number of figures wanted, is found, and this being a, we have found −0·000060831 for $-\phi a$, and −4·485316 for $\phi' a$. The first divided by the second may be depended upon for doubling the number of figures, as commonly practised in the extraction of the square root. [APPROXIMATION.] The figures 13562 are found by a contracted division shown in the example.

But it is more convenient to avoid decimals in the process, which may be done as follows. 1. If there be decimals in the coefficients of the equation, annex ciphers to every place in such manner that the number of decimals in the several places may be in increasing arithmetical progression. Then strike out the decimal points entirely, and proceed as with whole numbers, remembering that the root thus obtained will be 10 times too great if the progression increase by units, 100 times too great if it increase by twos, and so on. Thus $1{\cdot}81x^3-{\cdot}6x^2+33x+18{\cdot}4$ should be changed into $1{\cdot}81x^3-{\cdot}600x^2+33{\cdot}0000x+18{\cdot}40000$, and $181x^3-600x^2+330000x+1840000$ will give ten times the required root. 2. When all the whole figures of the root have been obtained, and the decimal part is about to enter the calculation, before attempting to obtain the first decimal figure annex a cipher to the first working column on the left, two ciphers to the second, and so on to the end. Then proceed with the new figure as if it were a whole number, and make a new involution. When this is finished annex ciphers again as before. One additional advantage will be that the ciphers will serve to mark the places of completion of the individual involutions. If in any case ϕa should not contain $\phi' a$, place a cipher in the root, annex ciphers again, and then proceed. In some of the older algebraists, Oughtred for instance, the several vertical lines of figures are kept in their places by a set of ruled columns, the use of which is difficult. Mr. Horner has a similar contrivance; but the employment of ciphers removes all the difficulty, as in common division and the extraction of the square root. See the last example in this article. The method might easily be extended to the whole part of the root. The following is an instance of the method:—

$$x^4+x^3-x^2-2x-2=0$$

1	−1	−2	2(1·414,2136
2	2	1	−1
3	1	−1	30000
4	3	4	28256
50	4	3000	17440000
54	4	4064	12206261
58	800	7064	52337390000
62	216	4992	49671698816
660	1016	12056000	2665691184
661	232	150261	2495754355
662	1248	12206261	169936829
663	248	150923	124787718
6640	149600	12357184000	45149111
6644	661	60740704	37436315
6648	150261	12417924704	7712796
6652	662	60847072	7487263
6656	150923	12478771776	
	663		
	15158600		
	26576		
	15185176		
	26592		
	15211768		
	26608		
	15238376		

Many of the preceding figures are useless, but we have judged it best to present the whole process. The best method of abbreviation is to fix a point of the process from and after which the number of figures in the last column is not to increase, striking off at every step one figure from the last column but one, two from the last but two, and so on. The consequence will be, that the several columns on the right will disappear one after the other; the process will be legitimately reduced to termination with a contracted division, independently of the theorem cited; and the result will be true to the last place. The effect of this will be, that as soon as the remaining part of the root is too small for its highest power to show itself in the process, an equation of the $(n-1)$th degree takes the place of the nth, and so on, until there remains only an equation of the first degree, and the approximation then proceeds by the Newtonian method. All this was pointed out by Mr. Horner, whose view of his own method was very complete, in everything but historical information. Had he given in his paper an example from Oughtred, also worked by his own method, pointing out the difference of the two, we feel sure that the question about the right to the invention never would have been discussed.

Taking up the preceding example at the point with which we left off (neglecting the division), and following the process, we have

(Root obtained 1·414) 213562373

6 | 656	15 23 83|76	124787 7 1 7 7|6	2665691184
Disappears	13	30 4 7 9 4	2496363944
at	15 23 97	124818 1 9 7 2	169327240
next	13	30 4 8 2 0	124850203
step.	15 24 10	124848 6 7 9|2	44477037
	13	1 5 2 4	37455657
	15 24|23	124850 2 0 3	7021380
		1 5 2 4	6242640
	15|24	124851 7 2|7	Dividend 778740
		4 6	749117
		124852 1|9	29623
		4 6	24970
	15|	124852 6|5	4653
		1	3746
	Disappears, leaving	124852 8	907
	1 for carriage.	1	874
—	Divisor	124852|9	33
			37

The answer 1·414213562373 is correct to the last place inclusive. (The contracted division follows the thick line.) The rule by which to judge of the extent to which the full process should be continued is as follows: Carry it on until the last column but one has at least two more figures than the number of root figures *remaining* to be found.

Such is the method which must place its author among those valuable inventors who find out simple adaptations which have been overlooked by their predecessors. It is not a little remarkable that this, the most important facilitation which the solution of numerical equations has received since the time of Vieta, and which is, *when known*, a very obvious extension of the extraction of roots, should have only preceded by a few years the most important addition to the method of ascertaining the number of roots which has been made since Des Cartes, and which is also, when known, an equally simple result of the process of finding the highest common factor of two algebraical expressions. [STURM'S THEOREM.]

Two of the most remarkable applications of this method are the solution of equations of the second degree, which is made as simple as the extraction of the square root, and the extraction of the cube root, which is reduced from an impracticably complicated process to one of perfectly easy performance.

As an example of the first, required the solution of

$$2x^2+x=2.$$

Since the root is less than unity, the preparation for decimals is made at the outset.

```
2    10       200(·78077643
     14       168
     24        3200
     14        3168
     380         320000
      16         288498
     396          31502
      16          28854
     41200         2648
        14         2473
     41214          175
         1          165
     4122            10
                     12
```

or $x=·78077643$, which is correct with the exception of the last place. The extraction of the square root, say of 10, is done by solving the equation $x^2+0x=10$; but it will be found that the solution of any equation of the form $x^2+ax=b$ may be performed by the same rule as the extraction of the square root. We shall show this, beginning with Horner's rule, and changing to the other after a few steps. Let the equation be $x^2+2x=10$.

```
2           10(2·31662479
4            8
60           200
63           189
660           1100
661            661
662     6626)43900
             39756
       66326)414400
              397956
        66332)16444
               13266
                3178
                2653
                 525
                 464
                  61
                  59
                   2
```

In the extraction of roots, the method of pointing and bringing down the periods as they are wanted may be followed. The following is the process for the extraction of the cube root of 205692449327; it being remembered that the question is the solution of an equation of the form $x^3+0x^2+0x=a$:—

```
1    0       0            205692449327(5903
     5       25           125
     10      7500          80692
     150     1431          80379
     159     8931            313449327
     168     1512            313449327
     17700   104430000               0
     17703       58109
             104483109
```

The following process is the extraction of the cube root of 1·808, and will serve as an example of the complete process, omitting only the first column, which, with the exception of the unit at the head, is blank. And this is also the type of the solution of any cubic equation whatsoever; the only difference being that the heads of the first and second working columns are ciphers in the extraction of the simple root, and significant in all other cases.

```
    00            000              1808(12·18239869783957002
  a 10            100 a                  ad·gjmpsvwxyzabcdefg
  b 20            100 aa           1000 aaa
  c 30            200 b             808
  d 32            300 b             728 ddd
  e 34             64 d              80000
  f 360           364 dd             43561 ggg
  g 361            68 e              36439000
  h 362         43200 e              35371232 jjj
  i 3630          361 g             1067768000
  j 3638        43561 gg              890260568 mmm
  k 3646          362 h              177507432000
  l 36540     4392300 h              133564300767 ppp
  m 36542       29104 j               43943131233000
  n 36544     4421404 jj              40070573018919 sss
  o 365460      29168 k                3872558214081|
  p 365463  445057200 k                3561857365704| vvv
  q 365466      73084 m                 310700848377|
  r 3654690 445130284 mm                267139491006| www
  s 3654699     73088 n                  43561357371|
  t 3654708 44520337200 n                40070925909| xxx
  u 3654717     1096389 p                 3490431462|
    x w v   44521433589 pp                3116627593| yyy
                1096398 q                  373803869|
          4452252998700 q                  356186010| zzz
               32892291 s                   17617859|
          4452285890991 ss                  13356975| aaa
               32892372 t                    4260884|
         |4452318783363 tt                   4007093| bbb
         |       292377 v                     253791|
         |445232170713 vv                     222616| ccc
         |      292377 v                       31175|
         |445232463090 v                       31166| ddd
         |        2192 w                           9|
         |44523248501 ww                          9| ggg
         |       2192 w                            0
         |44523250693 w
         |         32 x
         |4452325101 xx
         |        32 x
         |4452325133
         |gfedcbazy
```

The preparation for decimals makes the answer ten times too great; so that the cube root of 1·808 is 1·218...002, of which only the last figure 2 cannot be depended upon. The preceding contains every figure which need be written down, all the connecting operations being those which are usually performed mentally, and one only is required for each figure.

The vertical lines in the example show that part of the operation in which the contraction takes place, and the point at which the contraction becomes simple contracted division is marked by a thick horizontal line.

To enable the beginner to examine the process, we have placed a letter in every line of the first working column, by which the parts of the second column which are connected with it may be traced; while a letter doubled in the second column shows a multiplicand the product of which by the root figure is found as marked in the third column. The letters under the last line of the first column mark the figures cut off in the several contractions, and their results in the other columns are traced in the same way: the same for the letters under the second column.

One simplification might be made after the learner has practised a number of examples conducted as above. In the second working column, certain lines—namely, the second *b*, the second *c*, the second *h*, &c.—are not used except to be added to the next line. Hence, each of the lines on which a letter is doubled might be formed by adding the first, third, and fourth preceding lines, and the effect would be to omit some of the lines and some of the most simple additions. The second column, beginning from *pp* inclusive, is a specimen, and changing the line in which ciphers are annexed (and the ciphers should always be annexed to mark the step) would be—

44521433589	*pp*
109639800	*q*
32892291	*s*
4452285890991	*ss*
32892372	*t*
292377	*v*
445232170713	*vv*
292377	*v*
2192	*w*
44523248501	*ww*

But considering that the process is one which no person will very often perform, we doubt whether to recommend even this abridgment. All such simplifications tend to make the computer lose sight of the uniformity of method which runs through the whole; and we have always found them, in rules which only occur now and then, afford greater assistance in forgetting the method than in abbreviating it. But one abbreviation, when duly learnt, is found to have very great advantage. The addition of the products which are carried from each column to the next—and for the last column, the subtraction—might be made at once, figure by figure, as fast as the figures are formed.

On evolution of algebraical quantities we do not think it necessary to speak, since either the binomial theorem [BINOMIAL THEOREM], or some other method of development, is employed with more advantage than the usual modification of the arithmetical process. We have also omitted the process of division, the most simple of all evolutions, since its connection with the preceding is sufficiently obvious.

There is, however, a process of an evolutionary character which we take this opportunity of suggesting, and of which any one moderately conversant with algebra will easily arrive at the demonstration. In finding the highest common divisor of two algebraical integral expressions, and also in the process of Sturm's theorem, it is required to divide one expression, P, by another, Q, not for the sake of finding the quotient, but the remainder; and this remainder, cleared of all numerical factors and of fractions, is preferable. The following rule will render the application of Sturm's theorem much more easy:—

Question:—Two expressions, P and Q, being given, of which P is lower than Q, required the remainder of Q divided by P, cleared of fractions and of positive numerical factors. To take an example with us, let

$$P=2x^3-x-4$$
$$Q=4x^5-3x^4+2x^2-x+1.$$

1. Add 1 to the difference of the degrees $(5-3=2,\ 2+1=3)$: this is the number of operations to be expected. In this case it is three.

2. Write down in two lines the coefficients of the divisor and dividend, including the coefficient 0 for every missing term, but change the sign of every coefficient in the divisor, *except the first*. Clear both expressions of all whole factors; and if the two leading coefficients (2 and 4) have a common factor, divide by this factor before writing them down. Write ciphers in all blank places.

(P)	1	0	1	4	0	0
(Q)	2	−3	0	2	−1	1

3. Take the first vertical pair, and every other in succession, and make cross multiplication and addition: thus, $\begin{matrix} a & \cdot & \cdot & \cdot & c \\ b & \cdot & \cdot & \cdot & d \end{matrix}$ gives $ad+bc$. Put the first result in the first column, the second in the second, and so on.

(1)	−3	2	10	−1	1

4. Repeat this process with the first line, and the result just obtained, and again with the result, making each new result out of the first line and the last result, and so on till the number of operations ascertained in the first clause of the rule has been performed. But if the leading term of the first line have been divided, multiply that leading term again after the result, unless the first term of the result be also divisible by the same factor.

5. But if ever the first column of a result should turn out a cipher, throw it away, and bring forward the next column, and so on, making every step stand in the next higher place; and if the two first columns of any result should be ciphers, throw them away, and bring forward the third, and so on. And for every cipher thus thrown away, diminish by one the number of operations required in the first clause.

6. If any horizontal line thus obtained have a factor in all its terms, divide by that factor, taken positively, before proceeding further; and if the leading term of any new result have a factor in common with the leading term of the first line, divide both before proceeding.

The table of results now is as follows, in which the various changes of the leading terms are shown by putting them down as they occur, and putting a bar over them as they disappear and are replaced by others. In practice, the pen may be drawn through the figure which is dismissed.

(P)	$\bar{2}$, $\bar{1}$, $\bar{2}$, 1	0	1	4	0	0
(Q)	$\bar{4}$, 2	− 3	0	2	− 1	1
(1)	−3	2	10	− 1	1	
(2)	$\bar{4}$, 2	17	− 14	2		
(3)	17	− 12	10			

$17x^2-12x+10$ Answer.

7. When the last result has been obtained, make an algebraical expression one degree lower than the divisor, the coefficients of which are the numbers in the last result, with their signs.

The real remainder in the preceding example is $8\frac{1}{4}x^2-6x+5$.

Let the next example be

$$P=4x^3-6x^2+x+1$$
$$Q=2x^6-3x^5+2x^4+x^5-3x^3-3x+4.$$

Here the number of operations should be four; but it is reduced by the circumstance mentioned in the fourth clause of the rule.

(P)	$\bar{4}$, $\bar{2}$, $\bar{4}$, 2	6	− 1	− 1	0	0	0
(Q)	$\bar{2}$, 1	− 3	2	1	− 3	− 3	4
(1)	$\bar{0}$,* 3	1	− 6	− 6	8		
(2)	$\overline{22}$, 11	− 27	− 27	32			
(3)	12	− 65	53				

$12x^2-65x+53$ Answer.

The method of verifying the several processes, as their results arise, is as follows: Make an additional proof column, in which place the sums of the numbers in each line, taken with their signs; making these sums vary with the variation of the leading factors: thus

			Proof.
a	*b*	*c*	A
p	*q*	*r*	P
aq+*bp*	*ar*+*cp*	. . . . . .	Z

Here A is $a+b+c+\ldots$; P is $p+q+r+\ldots$; and Z is $aq+bp+ar+cp+\ldots$. If then the process be correctly done, an extension of it to the proof column gives $aP+Ap$, which ought to exceed Z by $2\,ap$.

We shall conclude this article with the process which will be applied hereafter. [STURM'S THEOREM.] The object is to proceed as in finding the greatest common divisor of P and Q, changing the sign of every remainder before using it.

$$P = 4x^3-9x^2-4x+1$$
$$Q = x^4-3x^3-2x^2+x-3$$

					Proof column.
4	9	4	− 1	0	16
1	− 3	− 2	1	− 3	− 6
− 3	− 4	3	− 12		− 16
− 43	0	− 45			− 88
43	0	− 45	0		− 2
4	− 9	− 4	1		− 8
− 387	− 352	48			− 696
− 15136	19264				4128
15136	19264				34400
43	0	45			

The remainders therefore, with the signs changed as directed, are $43x^2+45$, $15136x-19264$, and the last is a negative whole number. The following is the first instance of the use of the proof column:—

$$1\times 16+4\times(-6)-(-16)=8=2\,(4\times 1)$$

In the preceding part of this article we gave an account, with instances, of the method of solving equations, which is commonly known by the name of the late Mr. W. G. Horner, schoolmaster, of Bath. We believe we may usefully give what precedes a considerable extension: first, because the method [COMPUTATION] is one of the best exercises in computation; secondly, because neither its meaning nor its history is very generally understood, and the latter is very instructive.

The process of *involution* as above defined, is the formation of the value of a rational and integral algebraical expression, such as ax^3+bx^2+cx+d, by a succession of multiplications separated by additions, as in

$$\left\{(ax+b)x+c\right\}x+d.$$

Horner's mode of doing this takes the figures from left to right, or takes those of largest value first; and exhibits a plan of performing the operation which combines the result of each figure with the joint result of all that come before. Thus in finding the value of the preceding when $x=123{\cdot}456$ the value is first found when $x=100$; then, by help of the preceding, when $x=120$; then when $x=123$; then when $x=123{\cdot}4$; and so on. By this means we are enabled to proceed, when the value of the succeeding figures depends upon the results of those already found, as happens in all the cases of *evolution*, the inverse process. To take, however, the direct process first, we shall exhibit at length the finding of $9x^3-3{\cdot}141x^2+{\cdot}009x-1427{\cdot}499$, when $x=121{\cdot}23$; or, to avoid decimals in the expression, we may consider this as the thousandth part of $9000x^3-3141x^2+9x-1427499$. The process is as follows: a great many figures (about 115) being repeated twice over, in a manner wholly unnecessary in computation, in order to facilitate the explanation.

---

* Then bring forward the next column.

9000,	− 31,41	,0009	− 1,427499(121·23
	8968,59	8968,5909	8967,163401
	17968,59	26937,1809	A———
	26968,59	A———	8967163,401
	A———	2693718,09	15505343,181
	269685,9	3269089,89	B———
	287685,9	3880461,69	15505343181
	305685,9	B———	15896635209
	323685,9	388046169	C———
	B———	391292028	15896635209000
	3236859	394546887	15975675212760
	3245859	C———	D———
	3254859	39454688700	15975675212760000
	3263859	39520001880	15987553760654100
	C———	39585351060	———
	32638590	D———	
	32656590	3958535106000	
	32674590	3959515964700	
	32692590	3960496904400	
	D———	———	
	326925900		
	326952900		
	326979900		
	328006900		
	———		

We first put down the coefficients as usual, not changing the sign of the last (which is only a convenience for *evolution*, and does not alter any figure). The value of x being 121·23, we begin with 100, which, having two ciphers, we mark off by commas from the several coefficients 0, 2, 4, 6 places. We then proceed by Horner's process with the figure 1 (not 100), taking care to make commas fall under commas, or to use the commas as if they were decimal points (which they are in fact, though not *unit-points*). As soon as we have done the first process, containing all that comes before the lines A, we learn as follows. Let

$$\phi x = 9x^3 - 3{\cdot}141x^2 + {\cdot}009x - 1427{\cdot}499$$

then, x being 100, ϕx, $\phi' x$, $\frac{1}{2}\phi'' x$, and $\frac{1}{6}\phi''' x$ are severally 8967163·401, 269371·809, 2696·859, and 9. We then write down the results again, after the lines A (which is not necessary in calculation), merely to show the new disposition of the commas. We are now to proceed with 20 (from the first 2 in 121·23), which, having one cipher, we mark off 0, 1, 2, 3 places in the several columns. Immediately before the lines B we learn that when $x = 120$, ϕx, $\phi' x$, and $\frac{1}{2}\phi'' x$ are severally 15505343·181, 388046·169, and 3236·859. We then write down these results without any commas, and proceed with the second 1 in 121, from which we find that when $x = 121$, the functions are 15896635·209, 394546·887, and 3263·859. We then begin to provide for the decimal point, by annexing one, two, and three ciphers to the working columns, and taking the second 2 in 121·23 to work with, and applying Horner's process, we find, when $x = 121{\cdot}2$, that ϕx, $\phi' x$, and $\frac{1}{2}\phi'' x$, are severally (remembering that all the annexed ciphers are so many additional decimal places) 15975675·212760, 395853·51060, and 3269·2590. Finally, we annex the ciphers again, and with the 3 we find that $x = 121{\cdot}23$ gives 15987553·760654100, 396049·6904400, and 3280·06900.

Let us now compare the trouble of this process with that of any other method of doing the same. If we throw out all the figures which we have written twice over merely for explanation, and also the last two and one lines in the second and third columns, which are only wanted to go on further with, we have written down about 280 figures. The ordinary verification costs about 340 figures. It is true that every step is both a multiplication and an addition in one: but this can be done and ought to be done in the use of this method, and is not done in the ordinary method. And we have not only the advantage of a purely mechanical method, in which the first arrangement causes the succeeding steps to require nothing except a look at the successive figures of the value, but the still greater advantage of being able, at the end of the process, to make any small alteration of value with ease. If, for instance, having discovered that 121·297 would do better than 121·23, we wish to get additional accuracy, we have but to rub out the last 3 process, and proceed with 9 and 7. In the ordinary mode, we must either repeat the whole process again, or correct approximately by substituting 121·23—·003, which will require us to calculate $\phi' x$, and perhaps $\frac{1}{2}\phi'' x$.

We shall now exhibit a common multiplication, and the formation of a square; not, of course, that we attach any particular value to these simple cases, but that we may show the uniformity of the process. Required 14796 × 32316, or the value of $14796x + 0$ when $x = 32316$. We repeat the lines as before, which is more than is necessary, and makes this process look very long.

14796	0,0000(32316
	44388,0000
	443880,000
	473472,000
	4734720,00
	4779108,00
	47791080,0
	47805876,0
	478058760
Answer	478147536

Required the square of 279·46, or the value of x^2+0x+0, when $x=279{\cdot}46$.

1	,00	,0000(279·46
	2,00	4,0000
	4,00	400,00
	40,0	729,00
	47,0	72900
	54,0	77841
	540	7784100
	549	7806436
	558	780643600
	5580	780978916
	5584	
	5588	Answer 78097·8916
	55880	
	55886	
	55892	

The process here described is one which, we venture to say positively, has neither been put in its right place, nor received its due reward. It is the natural extension of the common process of multiplication, and its inversion is as naturally and necessarily the proper mode of solving equations, as the inversion of multiplication is the same for the simple equation $ax=b$, or common division. The inventor of it must rank, not with the analyst or the algebraist, commonly so called, but with the discoverer of the process of multiplication and division, and the extraction of the square root.

The application of this method to the solution of $\phi x = 0$ consists in finding the first figure by trial, and making use of the Newtonian approximation to find successive figures: namely, that if a be nearly a value of x, $a - \phi a : \phi' a$ is more nearly so. This method becomes difficult when two roots are nearly equal; but the difficulty lies in what may be called Newton's part of the complete method, not in Horner's part. When the difficulty of algebra shall be conquered, the process of arithmetic may easily be amended in the *trial part*; but to suppose that a capital improvement in the manner of conducting computations is little worth, because it is not accompanied by a victory over difficulties of quite another kind, is unreasonable. With a little more trial, Horner's method may be applied to the case of nearly equal roots; and as it is, it is more efficacious in discovering them than any other method.

To what has been said upon the method, we may add the following remarks:—1. When the last term is positive, and would in the ordinary process be made negative, it is often better, instead of changing the sign of the last coefficient only, to change the sign of all but the last. Thus in solving $x^3-11x+1=0$, the heads of the columns, should be − 1, 0, 11, and 1, instead of 1, 0, − 11, and − 1. Also, that if at any period of the process the divisor and dividend columns should become negative, the signs of all should be immediately changed.

2. In making the contractions, it will be advisable to make the figure which comes next after the separating line correct, to continue it, in fact, till the next contraction, and to use it to carry from. This is not done in what precedes, but it is done in the instance in COMPUTATION. In that instance, the following figures, seen one over the other in the last column but one, as follows, 3, 5, 7, − 6, 9, 1, − 2, 2, 2, are figures cut off by the contraction, but made up from the second column to carry from into the fourth.

3. If, at the beginning of the process, all the heads of the columns be multiplied by 9, the root will not be altered, and, until the contraction begins, the verification by casting out nines is rendered easy, since every result in every column is divisible by 9.

We shall now show how the process works in some equations which have equal, and nearly equal, roots.

Let $x^4-6x^2+9=0$, which has two roots, each equal to $\sqrt{3}$.

−1	0	6	0	9 (1·7320
	−1	5	5	40000
	−2	3	8000	1210000
	−3	000	5697	5041
	−40	−329	748000	3
	−47	−707	401653	
	−54	−113400	49132	
	−61	−115449	25190	
	−680	−117507	1220	
	−683	−119574		
	−686	−11971		
	−689	−11985		
	−692	−11999		

The existence of equal roots, or of nearly equal roots, might be here suspected from the slow increase of the divisor column; but the method cannot verify the fact of their being two absolutely equal roots. The column preceding the divisor column being large and negative, requires us to make trial of figures above, not below, those which the divisor column seems to indicate. But nearly equal roots may sometimes be detected, as in the following instance. Let $7x^3-10x^2-14x+20=0$, of which it is known that one root lies between 1 and 2. The ordinary process gives

−7	10	14	20 (1·41421356
	3	17	3000
	−4	1300	8000
	−110	748	1547000
	−138	8400	61608
	−166	6453	3859
	−1940	449900	1013
	−1947	371348	160
	−1954	292684	18
	−19610	288745	1
	−19638	284806	
	−19666	28460	
	−19694	28440	

This root may be carried on without difficulty. But at the end of the second process, when the dividend is reduced to 8000, the divisor only 8400, and the preceding column as much as −1940, it may be worth while to try another figure. This state of things gives a suspicion that there is another root in the immediate vicinity of the one in hand. If the three last columns be $+a, b$, and c, and if we find that $pa+b$ is nearly $c\div p$, which is the trial test of p being a new figure of the root, we are sure that $(p+1)\ a+b$ will not be near $c\div(p+1)$: and moreover $p\ (pa+b)=c$ has not two positive roots. But if the three last columns be $-a, b$, and c, it may very easily happen that $b-pa$ may be nearly $c\div p$, and $b-qa$ nearly $c\div q$; for $p\ (b-pa)=c$ has two positive roots. Perfect certainty, in the absence of an easy algebraical criterion, may only be attainable by trying every figure. In the instance before us, finding 1·41 succeed, with a presumption of a larger root, we try 1·43, beginning with

−7	−1940	8400	8000
	−1961	2517	449
	−1982	−3429	
	−2003		

This figure will not do, for now a permanent difference of sign is established between the dividend and divisor columns. We then try 2, as follows:—

−7	−1940	8400	8000
	−1954	4492	−984
	−1968	556	
	−1982		

There is now a difference of sign between the two last columns, but, looking at the second column, we see that agreement may be restored by the next figure. The figure 8 will do it, as follows:—

−7	−19820	55600	−984000
	−19876	−103408	−156736
	−19932	−262864	
	−19988		

and 26286400 is not contained 10 times in 156736000. All the signs being now negative, we may change them all. If we had tried 7 instead of 8, we should have had

−7	−19820	55600	−984000
	−19869	−83483	−399619
	−19918	−222909	
	−19967		

But now 22290900 is contained more than 10 times in 399619000, which shows that 7 is not high enough. If we try 9, we have

−7	−19820	55600	−984000
	−19883	−123347	+126123

and a permanent difference of sign is established between the two last columns, whence 9 is too high. Proceed then with

·7	199880	26286400	156736000	(1·428

and we find 1·42857142857 ... for a root. The reader may watch the operation in the following equation:

$$(9\,x-10)\,(9\,x-11)\,(30\,x-37)=0,$$
$$\text{or } 2430x^3-8667x^2+10293x-4070=0$$

the roots of which are 1·111 ..., 1·222 ..., and 1·233 ...

Whatever common figures two roots of $\phi x=0$ may have begun with, there must be a root of $\phi'.x=0$ which begins with these figures. And whatever common figures three roots may begin with, there must be two roots of $\phi'x=0$, and one root of $\phi''x=0$ which begin with those figures: and so on. If there were a difficult equation having three roots nearly equal, no method of detecting them would be easier, of all those known at present, than solving contemporaneously the three equations $\phi x=0$, $\phi'x=0$, $\phi''x=0$, not making any step in one till all had been brought up; that is, one step of each first, then the second of each, and so on.

It may happen that a finite root is established, and yet that the process must be continued to obtain another root beginning with the same figures. For example,

$$9x^3-46x^2+75x-38=0$$

It will be seen in the following process that 2 is a root, with a presumption, from the appearance of the divisor column and the one before it, that there is another root beginning with 2. And by trial 2·1111 ... is found to succeed.

9	−46	75	38 (2·11111
	−28	19	0
	−10	−100	11000
	80	−11	1221
	89	8700	23
	98	9779	12
	1070	10867	1
	1079	10977	
	1088	11087	
	1097		

We shall now proceed to a short account of the history of this problem, and of the controversies which have existed, and to some extent still exist. For a fuller account of it up to the time of Mr. Horner, see a paper by the writer of this article in the 'Companion to the Almanac,' for 1839.

Before the time of Vieta, evolution consisted in the rules for the performance of division, and extraction of the square and cube roots, in forms probably derived from the East. To him [VIETA, in BIOG. DIV.] we owe the first publication of a numerical method of finding the successive figures of the root of an algebraical equation by means of the value of the function equated to zero in the equation. This method of Vieta is in fact that which Horner's process now makes so easily practicable. If $\phi x=0$ be the equation, and a a part of the root, it uses ϕa, and $\phi\,(a+1)-\phi a$ as a divisor. The process is so cumbersome, that Vieta does not attempt to apply it to equations having more than two figures in the root.

This method attracted but little attention on the continent: but in England, where everything relating to numerical calculation has been always diligently studied, it was much noticed, and received extensions of power. In the posthumous work (1631) of Harriot [HARRIOT, in BIOG. DIV.] examples of it are given with the improvement of forming only so many figures of the divisor as are wanted: and he ventures upon roots of three places. In the second edition of Oughtred's 'Clavis Mathematica' (1647) Vieta's method is given without Harriot's improvements. But the first who used Vieta's method to any great extent was Briggs, in the calculation of the sines, &c., in the 'Trigonometria Britannica.' In the preface the method is applied to equations of the third and fifth degrees, and partially described for the seventh and higher degrees: with examples carried to fifteen and sixteen figures of the root. It is for the facilitation of these solutions that the Abacus παγχρηστος is given, which some have unreasonably interpreted as giving Briggs a claim on the binomial theorem. Gellibrand tells us that Briggs formed his tables of sines by algebraic equations and differences about thirty years before his death. Now Briggs died in 1630, and Vieta's tract appeared in 1600: the former must then have received the work soon, immediately seen the importance of the method, and commenced operations by means of it. We cannot give Briggs any independent title to the invention; for it is likely enough that he was in correspondence with Vieta, whose works he certainly knew. One of his examples is the solution of what would now be written

$$x^3-3x=1{\cdot}298896096660366$$

for which he gets $x=1{\cdot}917639469736386$. He puts down the work as far as ... 697, proceeding towards the end by several figures at a time: and he has got what Vieta had not, the Newtonian divisor $\phi'x$ instead of $\phi(x+1)-\phi x$. Of course it adds materially to the historical value of this method that it was thus used in an operation of so much importance to the progress of mathematics in general. The dates above given may even cause a suspicion that it was the power of solving equations thus suddenly acquired, which first suggested the calculation of the natural sines, &c., in the 'Trigonometria Britannica.'

Wallis, in his Algebra (1684), gives the method of the "*numerose exegesis*," as he calls it (Vieta had called it *potestatum adfectarum ad exegesin resolutio*) with an example of the fourth degree worked to seventeen places of the root. He makes use of the method of contracting the figures towards the end. In this same Algebra appeared, for the first time, what is called Newton's method of approximation, which soon superseded the exegesis, into which however it had been virtually incorporated by Briggs. Newton's approximation, at least in the general form which it took in the hands of Taylor, is as follows. If a be a near value of x in $\phi x=0$, then, except when there are two nearly equal roots, a nearer value is

$$a-\frac{\phi a}{\phi' a}\text{ or }a+\frac{-\phi a}{\phi' a}$$

The old exegesis, and especially Briggs's form of it, employs this principle: — ϕa is calculated, and either $\phi' a$ or $\phi(a + 1) - \phi a$. Briggs, who proceeds by several figures at a time, and uses $\phi' a$, does really use what was afterwards called Newton's method, and assists it by operations suggested by Vieta.

When the exegesis was abandoned by Raphson and others, in favour of Newton's form of operation, no further improvement was made in the direct numerical solution of equations, until the time of Mr. Horner; at least no further improvement was published. Mr. Henry Atkinson, a young man of Newcastle, re-invented the whole method in 1801, applying Newton's divisor, and giving rules by which one divisor was made to help in forming the next. This was read to the Philosophical Society of Newcastle in 1809, and published posthumously, as 'A new Method of extracting the Roots of Equations,' Newcastle, 1831, 4to. In our article in the 'Companion to the Almanac, already cited, we have supposed that no one can be shown either to have used $\phi' a$, or to have made each value of it help the next, before Mr. Atkinson: but we now find that Briggs was before him in both points.

Lagrange's method of transforming the root into a continued fraction [THEORY OF EQUATIONS] does not need notice here, because it belongs to another mode of expression. But it ought to be noticed that Horner's process very much abridges the labour of Lagrange's method, as much indeed as it does that of Vieta's exegesis, and for the same reason. Mr. Exley, of Bristol, in the 'Imperial Encyclopædia,' article ARITHMETIC, improved (according to Horner himself) the common method of extracting the cube root, so as to precede Horner in this particular case. We believe more than one method had been given for reducing the enormous labour of the ordinary extraction of the cube root: we may mention one, which is ingenious and effective, and almost exactly a particular case of Horner's method, given by Mr. A. Ingram, in his edition of Hutton's 'Arithmetic,' Hawick, 1811, 8vo.: and Horner himself refers to an edition of Melrose's 'Arithmetic,' by Mr. Ingram (the same, we suppose) as containing such a method.

Horner's paper was read to the Royal Society on the 1st of July, 1819, and was published in the current volume of the Transactions, on the 1st of December. These dates are of importance: the publication of the above paper was the signal for more than one person to make a nibbling claim to the invention. Horner was unfortunate in two points. First, he had not sufficient knowledge of ancient algebra to be aware that his method contained the process of Vieta, and that his real claim consisted in the discovery of the beautiful process by which the labour is immensely reduced, and completely systematised: we suspect that he completely re-invented Vieta's part for himself. Secondly, he appears to desire to be the analyst rather than the arithmetician, and will not show anything except to those who can take all. It is true, beyond a doubt, that his method is adapted to every sort of equation, and that it is as great a help to the person who desires to solve $\tan x - ax = 0$, or $\epsilon^{\sin x} = x$, as to the other who wants nothing but a common algebraical equation. So far, then, it is more than Vieta's method simplified; it is the same also extended. But if the inventor had proceeded from simple algebra to the more complicated cases, his merits would have been more rapidly appreciated. He did not well see that his mode of solution applies as well to the integer part of the root as to the fractional; nor did he fully comprehend how much of his own discovery consisted in the general mode of calculating the value of ϕx, as given at the beginning of this article. But that we may not do him injustice, and still more that we may enable those of our readers who have not access to the original paper to see how completely he had got hold even of the most convenient arithmetical process, we give his solution of the famous Newtonian instance $x^3 - 2x = 5$. After reducing the root by 2, the heads of his columns are 1, 6, 10, and 1 (the first column, which is always vacant, he does not set down). He then annexes either dots or ciphers, and proceeds exactly as follows

```
                                           .  .  .
      6. .         10. . . .          1000000(·0945514815
     ----
      609            5481               949829
      184          105481              50671000
    62|74            5562. .           44517584
      |.8             25096             6153416
  ..|62|82         11129396             5578825
                     2511|2              574591
                      314|12             558055
                  111576 4|92    1, 1, 1, 6, 1)16536(14815
                      31 4|1              11161
                       3|1|4               5375
                  111611|0|4               4465
                       3 1                  910
                  11161|4|1                 893
                                             17
                                             11
                                              6
                                              6
```

When Mr. Horner's paper had been published six months appeared 'A new Method of Solving Equations,' by Theophilus Holdred, London, 1820 (preface dated June 1), 4to. The method is taken from Harriot; and a supplement is added, which gives Horner's method. Both are claimed as independent inventions, and Horner's name is not mentioned. Mr. Holdred asserts that, after having had his method for forty years he was led to that in the supplement * by a mistake he committed in solving an equation sent him by one of his subscribers. We have given, in the article of the 'Companion to the Almanac,' already cited, our reasons for coming to the conclusion that Mr. Holdred took his first method from Harriot, and his second from Horner.

A claim was made by Mr Peter Nicholson in various places, which is quite futile. We acquit Mr. Nicholson (a highly respectable man, eminent in the application of mathematics to the arts) of all unfair intention: and we must remind our readers of a point without the knowledge of which the various controversial writings on this subject will be full of confusion. Hardly any one knew of Vieta's Exegesis, which there is little doubt that both Horner and Atkinson reinvented. In fact, so completely had this exegesis dropped out of sight, that even Dr. Peacock, in his short account of Horner's method ('Report on Analysis to the British Association') does not allude to it. Accordingly, all the re-inventors of Vieta's method speak of quite new rules discovered for the solution of equations, and treat Horner's process as a constituent part of one of the new inventions. But a person acquainted with the history of the subject finds nothing new except Horner's process. Vieta had the main system, Briggs had the Newtonian divisor, Wallis had the method of contraction, Briggs had *a* method of making one divisor help the rest: Horner had *the* method which must finally be adopted. Budan, as we shall see, had only a particular case of that method, and did not apply it to any mechanical process of numerical solution.

Mr. Nicholson claims Horner's identical process, and fairly refers to the very place in which he says it is to be found. But on looking there (see the article already cited in the 'Companion to the Almanac'), we find that he has been deceived by a distant resemblance, and that, though he has given a new and useful process for a useful purpose, neither the process nor the purpose is Horner's. At the same time it is but justice to Mr. Nicholson to say, that in his 'Elements of Algebra,' London, 1819,† 12mo, he made as near an approach to Horner's method as could well be done, and applied it in the case of equations of the second and third degrees. The succession of columns is seen, each column helps the next, and each step in any one column helps the next step. But the grand simplification, which the controversialists called the "non-figurate method," is wanting: so that this process of Nicholson's is perhaps hardly more than Briggs was in possession of. Mr. Nicholson had received Mr. Holdred's method, whose name he properly mentions in the preface. This method he had greatly improved; and it seems he wished that Holdred should publish his own method as amended by him; but he asserts (in the preface to his work on Involtion and Evolution) that the latter refused, alleging that his own credit would be diminished, unless he could pass them as his own.

Dr. Peacock had never seen Holdred's tract, and his result, derived from the assertions of Mr. Nicholson and from Horner's paper, is that Nicholson, by a combination of the methods of Holdred and Horner, reduced the method to its present practicable form. But any one who will solve $x^3 - 2x = 5$ in the systematic form we have given, will see that Horner had that form. Nicholson was, we believe, the one who first clearly saw that the method, in its simplest organisation, applies as well to the integer as to the fractional portion of a root. All Mr. Nicholson's simplifications, as given in his latest writings, consist in doing in the head some of the things which Horner put down on paper. The form we give carries this still further; and those who can do what we have recommended all arithmeticians to practise in COMPUTATION can follow us: but there is no invention in this.

Some have been disposed to give a good deal of the merit of this system to Budan; and his claim must be considered. Two editions of the 'Nouvelle Méthode pour la Résolution des Equations numériques,' Paris, 4to., were published in 1807 and 1822. The basis of M. Budan's operations is the simple case of Horner's process in which the root of an equation is diminished by unity. This is done exactly in the mode by which Horner afterwards proceeded. Thus to lessen the root of $x^3 - 2x - 5 = 0$ by unity, Budan proceeds thus:—

$$\begin{array}{rl} & 1+0-2-5 \\ & 1+1-1-6 \\ (\text{A}) & 1+2+1 \\ & 1+3 \\ & 1 \end{array}$$

$$\text{Answer } x^3 + 3x^2 + x - 6 = 0$$

But to lessen the root by 2, Budan is never able to arrive at the process on the left, which is Horner's: he must repeat the process of diminishing the last root by one, as on the right.

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* We cannot but believe that Mr. Holdred did see Mr. Horner's paper. Had he mentioned it, and the name of the subscriber, his equation, the mistake made, &c. &c., distinctly declaring when and where he first saw Mr. Horner's paper, he might have possibly established a claim to be a second inventor.

† The preface is dated May 17, 1819, and the publication took place early in July, Mr. Horner's paper having been publicly read at the Royal Society on the first of that month.

	$1+0-2-5$	$1+3+1-6$	
	$1+2+2-1$	$1+4+5-1$	
(B)	$1+4+10$	$1+5+10$	(C)
	$1+6$	$1+6$	
	1	1	

Accordingly Budan has both (A) and (C) to do, where Horner has only (B). To diminish a root by 3, Budan has 3 processes, and so on. To diminish a root by 10, 20, &c., he divides the roots of the original equation by 10, then diminishes by 1, by 1 more, &c., and then multiplies the resulting roots by 10, 20, &c.; and similarly for 100, &c. It is obviously possible, by a large amount of calculation, to obtain the root of an equation in this manner; but Budan is not only obliged to call in other methods, and even thus to spend very great labour, but he ends by presenting the root in the form of a sum of common fractions, each of which must be reduced to a decimal. Thus for $x^3-2x=5$, he gets

$$x=2+\frac{1}{11}+\frac{1}{275}+\frac{1}{165925}=2{\cdot}094551481364$$

Budan's method is not then even of the same species [*] as Horner's. In an appendix added to the edition of 1822, two years after Horner's paper, there is the method extended to the process for diminishing the root by n (Horner's process), but no use is made of it, and singularly enough the only example given is one in which n is -1.

Horner ('Leybourn's Repository,' page 38, of part ii., vol. v.) denies ever having seen Budan's work until 1818, after his method was finished. This, in one point of view, counts for nothing; for every discoverer has a right to have it supposed that those who come after him have used his works: that is to say, the first discoverer would have a right to the credit therefrom arising, even though it could be shown that subsequent discoveries were made without his aid. If a partial or unfinished method turn out to have a value of quite a new character when made complete, it is impossible to deny to its author the credit of having been further than his contemporaries on the road towards the complete method: consequently, Budan must have, in one sense, the merit of having proposed a particular case of that which Horner afterwards used. But, as it happens, a contemporary of Mr. Horner, in trying to insinuate that Horner had taken his method from Budan, has furnished independent evidence to the contrary. Mr. Nicholson, in a note to the preface (page ix.) of his essay 'On Involution and Evolution' states: "I am informed by Mr. Dickson that about twelve months ago he (Horner) purchased at his shop, in St. Martin's-le-Grand, an 'Essay on the Numerical Solution of Equations,' by Budan; at which time he mentioned that he was engaged expressly on this subject." This called forth the preceding statement from Mr. Horner, who, had he any unfair intention, and had he really been indebted to Budan, would have argued from the date of Mr. Nicholson's preface that he must have bought Budan only just time enough to insert the note about him in his paper before he sent it to the Royal Society. Instead of this, he answers in the most straightforward manner, that he bought Budan about July, 1818, nearly *two* years before Mr. Nicholson wrote; but avers that his method was then finished. And this we entirely believe; and also that it would have been impossible for him, fully engaged as he was in teaching a school, to have produced his method, so as to send it to the Royal Society in the spring of 1819, if he had only seen the first hint in the summer of 1818. But had he seen Budan's work, and had he thence derived the hint which he improved, his merit would not have been the less: Lagrange, the greatest writer on equations then existing, had seen it; Legendre had seen it: and both had closely examined it, and reported to the Institute upon it. The members of the Institute had seen it. Lagrange, too, knew of Vieta's Exegesis. But no one, except the Bath schoolmaster, ever brought forward Budan's method, or any extension of it, either from Budan, or independently, to the improvement of Vieta. Fourier had seen Budan's book, and had invented a method of his own of solving equations; or rather had given his own mode of conducting Newton's approximation; but this method is far below that of Horner.

We have written so much on the discovery of this method, because unfair attempts were made by claimants who had no title whatever to deprive the author, who was a man of real genius, of his rights over his own discovery. We refer to MM. Holdred and Nicholson: though we do not believe the second was knowingly unfair. Mr. Atkinson, when he first saw the "non-figurate method" (as some called the subject of this paper), saw and said that it was a "capital improvement." We have written also because it can hardly yet be said that mathematicians are alive to the value of this grand completion of the system of arithmetic. The continental writers show no knowledge of it; the Oxford and Cambridge elementary works do not yet recognise its existence, except so far as this, that one very recent Cambridge edition makes an imperfect introduction of it. The fact is, that mathematicians dislike calculation, and are apt to form hasty opinions on numerical methods before they have given them sufficient trial. The first elementary writer who brought Horner's method into instruction was Mr. (afterwards Professor) Young, in his 'Elements of Algebra,' published in 1823.

In 1831, eleven years after this method was published, appeared Fourier's posthumous work on equations, containing an extended use of Newton's method. It amounts to employing ϕa, $\phi' a.h$, $\frac{1}{2}\phi'' a.h^2$, &c., to calculate the value of $\phi(a+h)$, and $\phi' a$, $\phi'' a.h$, &c., *separately*, to calculate $\phi'(a+h)$; and so on. Fourier was an expert arithmetician, and in this very work shows his power of suggesting new forms of arithmetical process; but he does not come near anything like making the previous calculation of $\phi^{(n)}(a+h)$ give assistance to that of $\phi^{(n-1)}(a+h)$. The equation $x^3-2x=5$, which Wallis happened to take as his instance of Newton's method, has always been the example on which numerical solvers have shown their power. No one can be said to have carried a method beyond those which preceded, unless he has solved this equation to more places than they have done. Fourier went to thirty-two decimal places, which we do not know that any one had done before. Some students of University College, London (and one of King's College), none exceeding eighteen years of age, carried Horner's process further still, their independent calculations giving root to 52 figures. Some years afterwards, another student of University College, Mr. W. H. Johnston, of Dundalk, carried the solution to 101 decimal places, and verified it by the independent solution of a related equation. In 1851, Mr. J. Power Hicks, of Lincoln College, Oxford, then a student of University College, carried the solution to 152 decimal places, never having seen Mr. Johnston's result, with which, so far as it went, his own agreed. This last solution[*] is as follows, and it took about 50 hours of calculation:—

2·09455,14815,42326,59148,23865,40579,
30296,38573,06105,62823,91803,04128,
52904,53121,89983,48366,71462,67281,
77715,77578,60839,52118,90629,63459,
84514,03984,20812,82370,08437,22349,
91

We insert this conclusion as a challenge to any who still hold the opinion, which as a matter of course was maintained by some when Horner's method first appeared, that some older methods were superior to it. There were those who thought that the method of trial and error, or of false position, as it was called, was preferable. Mr. Nicholson gives, as the work of a young computer, the following solution of

$$4x^6+7x^5+9x^4+6x^3+5x^2+3x=792$$

$$x=2{\cdot}05204,21768,79605,36521,40434,01281,20197,34602,75599,54554\ 17242,14$$

An able[†] calculator informs us, that he makes the figures after 197 to be 34660, 87786,99113,74218,13787,467.

We have left entirely out of sight all the irrelevant controversy relating to the method of finding the limits of the roots, conducting the process when two roots are nearly equal, and so on. The claims of Budan, Fourier, Horner, &c., are here mixed up in a manner which requires a sifting investigation. Very frequently the value of Horner's method is stated as depending upon points of this kind. When any of the doubtful cases arise, which we noticed at the beginning of this article, we find, for ourselves, that the ease with which repeated trials are made by Horner's process gives us more command of these questions than anything else; in fact Fourier's theorem [STURM'S THEOREM] is very easily brought to bear by means of it. But it must be admitted that all methods which in any way include the Newtonian approximation are imperfect, when roots are nearly equal, in not having a better addition to the root a already obtained than $-\phi a : \phi' a$. Let a better method come, and we have no doubt that Horner's process is more ready to make easy use of it than any other. A student who is very slow at finding out the trial figures of common division, might as reasonably depreciate the rule of division altogether, as quarrel with Horner's method because there is now and then a difficulty in ascertaining whether or no more than one figure will do to proceed with.

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[*] He recommends that when more than *two* or *three* decimals of a root are wanted, the work should be turned over to *workmen* (*manœuvriers*) who are to be a distinct class from the mathematicians. The best comment on this will be to insert in this little *foot* note every figure of the work *for six* places of the equation on which this remark was made, with a guess at the *seventh*.

1	0	−2	5 (2·0945515
	2	2	1000000
	4	100000	50671
	600	105481	6153
	609	111043	574
	618	111294	16
	627	111545	5
		11157	0
		11160	

[*] As there is always a liability to defacement of figures, we give the sums of the digits in the horizontal and vertical lines. The sums in the horizontal lines should be 137, 115, 140, 157, 121, 10. The sums in the vertical lines should be 2; 32, 23, 27, 16, 24; 16, 25, 28, 25, 21; 20, 17, 29, 14, 25; 28, 23, 16, 20, 25; 27, 13, 30, 17, 26; 18, 16, 15, 26, 36.

[†] Mr. A. Davis, assistant master in University College School.

The same difficulty must exist in every method, as matters now stand. In the meanwhile, we think the discoverer of the process, which is now beginning to take its proper place, deserves attention to his request when he says, speaking of the antagonist claims which had started up—"All I ask of them (mathematicians) in recompense for the facilities consigned to their use in the non-figurate method, is to bear in mind that I alone am the author of it." And we have no doubt whatever, and are willing to stake our credit upon it, that when the inertia of the higher mathematicians in matters of computation is overcome, and when the mode of solving equations has reached the schoolboys, as it is rapidly doing, the name of Horner will be one of the household words of pure arithmetic, and himself looked upon as one of the greatest of its modern benefactors. Justice requires that his name should remain attached to his process.

IOD or IODO. A prefix used in chemistry to signify that the body to the name of which it is attached contains iodine substituted for some other element. Such compounds will generally be found described under the name of the body to which this prefix is attached.

IODAL ($C_4HI_3O_2$) *Hydride of tri-iodacetyl.* A body analogous to Chloral, said to be produced by mixing alcohol with nitric acid and then adding iodine. Its existence has not been satisfactorily established.

IODANILINE ($C_{12}H_6IN$). A derivative of aniline. [Aniline.]

IODHYDRIN ($C_{12}H_{11}IO_6$). A liquid compound produced by the action of hydriodic acid upon glycerin. [Glycerin.]

IODIC ACID. [Iodine.]

IODIDES. [Iodine. *Hydrogen and Iodine.*]

IODINE (I), a non-metallic, elementary, or simple solid body, discovered by M. Courtois, of Paris, in 1812. Its peculiar properties were however first ascertained by Gay-Lussac and Davy. Iodine exists in the water of the ocean and mineral springs, probably combined with sodium, or calcium, or magnesium; also in marine molluscous animals and sea-weeds; and has been met with in combination with silver. Iodine is principally obtained from *kelp*, or sea-weed which has been burnt for the purpose of obtaining alkali from it. When the alkaline and other salts have been separated from this ash, the residual solution is treated with sulphuric acid and binoxide of manganese, by which the iodine is set free, the decomposition being analogous to that by which chlorine is obtained by the same agency from common salt.

$$\underbrace{NaI}_{\text{Iodide of sodium.}} + \underbrace{MnO_2}_{\text{Binoxide of manganese.}} + \underbrace{2SO_3}_{\text{Sulphuric acid.}} = \underbrace{NaO, SO_3}_{\text{Sulphate of soda.}} + \underbrace{MnO, SO_3}_{\text{Sulphate of manganese.}} + \underbrace{I}_{\text{Iodine.}}$$

The process is conducted in leaden retorts of cylindrical form, and heated on a sand-bath to a temperature not exceeding 212° Fahr., a higher heat than this causing loss from the formation of chloride of iodine. At this temperature the iodine slowly vaporises, and passing off through the neck of the retort is condensed to the solid form in a series of flasks connected together by the neck of each passing through a hole in the bottom of the one preceding it.

Iodine is a soft opaque solid, of a bluish-black colour and metallic lustre. The primary form of the crystal is an acute rhombic octohedron. The crystals are usually flat. According to Gay-Lussac, its specific gravity is 4·947. When moderately heated, it rises in vapour of a violet colour, and hence its name from the Greek (ἰώδης, "violet-coloured"). On cooling, it again crystallises unchanged, nor is it altered by being subjected to very high temperatures; it has resisted all attempts to decompose it. Iodine has a strong disagreeable odour and taste, somewhat resembling bromine and chlorine; it stains the skin of a brownish colour, but not permanently. It is readily dissolved by alcohol, and the solution is of a reddish-brown colour; so little is taken up by water that a pound of that liquid will not dissolve more than a grain of iodine. It is very poisonous. Its characteristic property is that of giving an intense blue colour when added to a solution of starch. It unites with metals to form compounds, termed *iodides;* these are all decomposed by chlorine, or even bromine, iodine being liberated. They will be found described under the names of the respective metals. Iodine, like chlorine and bromine, forms acids both with hydrogen and oxygen.

The equivalent of iodine is 126·8; its combining volume, 2; and the specific gravity of its vapour, 8·716.

Oxygen and Iodine combine to form probably four compounds. When the vapour of iodine and oxygen gas are mixed at rather a high temperature, the violet tint of the iodine disappears, and a yellow soft substance is formed, which is regarded by Sementini as *oxide of iodine;* if this be subjected to the action of more oxygen gas, it is converted into a yellow liquid, which the same chemist supposes to be *iodous acid;* but the composition and properties of these compounds have not been accurately determined.

Iodic Acid (IO_5).—This compound was first obtained by Davy by the action of iodine upon what he called euchlorine gas. A better process however consists in heating the iodine in the strongest nitric acid. For this purpose the acid should be introduced with about a fifth of its weight of iodine into a capacious retort, and kept boiling for 12 hours; the iodine which rises and condenses on the sides of the retort is to be returned to the acid either by a glass tube or by agitation; when the iodine disappears, the excess of nitric acid is to be got rid of by evaporation. Iodic acid is a white semi-transparent solid substance, which may, however, be obtained in crystals containing one equivalent of water (HO, IO_5). It is inodorous, but has an astringent sour taste. It is so dense as to sink in sulphuric acid, and it deliquesces in a moist atmosphere. It is very soluble in water; the solution reddens vegetable blue colours; it detonates when mixed and heated with charcoal, sugar, and sulphur. When crystals of iodic acid are heated to 360° Fahr., they become anhydrous, and at about 700° are decomposed into iodine and oxygen. Iodic acid combines with metallic oxides to form salts, which are termed *iodates*, containing one, two, or three atoms of acid to one of base, and these, like the chlorates, yield oxygen when heated; an iodide remaining.

Periodic Acid (IO_7).—When chlorine is added to saturation to a solution of iodate of soda with excess of the alkali and concentrated by evaporation, a sparingly soluble white salt is obtained, which is *periodate of soda;* when this is dissolved in dilute nitric acid and mixed with nitrate of silver, a yellow precipitate falls, which, dissolved in hot nitric acid and evaporated, yields orange-coloured crystals of periodate of silver; these are decomposed by cold water, and an aqueous solution of pure periodic acid formed; this by cautious evaporation yields crystals, containing five equivalents of water of hydration. When heated to 212°, they are resolved into oxygen and iodic acid.

Nitrogen and Iodine appear to form three distinct compounds, containing respectively NH_2I, NHI_2, and NI_3, derived no doubt from ammonia (NH_3) by the substitution of hydrogen by iodine, thus:—

$$N\left\{\begin{matrix}H\\H\\H\end{matrix}\right. \qquad N\left\{\begin{matrix}I\\H\\H\end{matrix}\right. \qquad N\left\{\begin{matrix}I\\I\\H\end{matrix}\right. \qquad N\left\{\begin{matrix}I\\I\\I\end{matrix}\right.$$

Iodide of nitrogen, or probably, a mixture of the iodides, is best prepared by dissolving iodine in aqua regia, and pouring the mixture into strong solution of ammonia; it then precipitates as a puce-coloured powder; or iodine may simply be powdered and digested at once in the ammonia, when an iodide remains insoluble in the state of a dark brown powder. This compound is very explosive, especially when dry: the best method of exhibiting its power is that of allowing it to dry in small portions on bibulous paper, and then simply letting it fall on the ground or merely touching it, when it detonates with a sharp noise, heat and light being emitted, and the vapour of iodine and nitrogen gas evolved. It is not dangerously explosive in quantities of 3 or 4 grains.

Hydrogen and Iodine form hydriodic acid (HI), which may be prepared by the direct combination of its elements. When a mixture of iodine in vapour and hydrogen gas is passed through a red-hot porcelain tube, they combine to form this acid. It is however much more conveniently formed by heating in a retort ten parts of iodide of potassium, five of water, and twenty of iodine, and cautiously dropping in one part of phosphorus cut into small pieces; hydriodic acid then passes over in the state of a colourless gas, and may be collected by displacement in dry bottles. This acid has a sour taste, reddens vegetable blues, and when mixed with atmospheric air forms dense white fumes with its moisture: its odour resembles that of hydrochloric acid gas. It is soluble in water. The salts which it forms are termed *iodides.* When it is acted upon by metals, hydrogen is evolved, and when by metallic oxides, water is formed, and in both cases iodides result.

It is decomposed by oxygen when they are heated together; water is formed, and iodine evolved. It is also immediately decomposed by chlorine, which unites with its hydrogen to form hydrochloric acid, and iodine is set free.

Chlorine and Iodine form two chlorides. The *protochloride* (ICl) may be obtained by passing a current of chlorine gas into water in which iodine is suspended. A deep reddish solution is formed that yields irritating fumes possessing the smell of both the elements: it first reddens and then bleaches litmus paper. The *terchloride* (ICl_3) is best formed by acting upon iodine with excess of dry chlorine gas. It forms fine ruby-red crystals.

Bromine and Iodine form compounds corresponding with the chlorides.

Sulphur and Iodine.—Four parts of iodine and one of sulphur combine on the application of gentle heat, and yield a product of dark colour and radiated crystalline structure. It is easily decomposed by heat.

Phosphorus and Iodine unite in two proportions. The *biniodide* (PI_2) is formed by dissolving one equivalent of phosphorus in bisulphide of carbon, and adding two equivalents of iodine. On cooling the mixture to a very low temperature, acicular crystals of orange colour are deposited. The *teriodide* (PI_3) is produced in a similar manner to the last, three equivalents of iodine being used instead of two. It forms dark red tabular crystals.

Carbon and Iodine appear to form no true compound.

IODINE, *Medicinal Properties of.* Iodine, though only obtained in an isolated state in the year 1811, has been long employed as the efficient principle of other preparations and therapeutic agents, namely, burnt sponge and certain mineral waters. [Water, subsect. *Mineral*, in Nat. Hist. Div.] It is only since it has been procured as a distinct principle that its action has been ascertained with precision. In the present day it is administered rather in some artificial compound than as pure iodine, owing to its very sparing solubility in water. Iodine in substance, however, when applied to the skin, stains it brown, and even the very small quantity which can be dissolved in water is sufficient to cause rubefaction, and in the form of baths produces decided action both on the surface of the body and the general system. When applied to ulcers or any breach of the skin, it occasions heat and a sense of pricking and tingling; it is also absorbed, and may be discovered in the blood and secretions of the patient. Taken internally, even in small doses, it causes a sense of heat in the mouth and throat; if much diluted by the vehicle in which it is given, and the stomach be healthy, it appears to do little more than increase the digestive powers; but in larger and stronger doses it creates great heat in the region of the stomach, which becomes sensible to pressure, with a feeling of weight, heartburn, and often nausea and vomiting. In very large doses it acts as an irritant poison. It is not merely an irritant poison when taken in a large dose, but is a slow or accumulative poison, even when taken in medicinal doses for a length of time, inducing a peculiar state called *Iodism*. It has been generally represented as causing emaciation even to a frightful extent; but though this has occurred in some instances, it does not seem to be frequent, if we except the absorption of certain glands, especially the mammæ of females.

The diseases in which it has been found useful are glandular swellings, especially bronchocele or goitre, which rarely resists its action; in some strumous diseases, in chronic rheumatism, and also as an antidote against poisoning with strychnia, brucia, and verataria: but its claims to confidence are not clear in case of such formidable poisons. It is often of use in lessening the injurious effects of mercury and in the treatment of the sequelæ of syphilis. (See Lugol, 'On Scrofula.') A liniment composed of iodide of potass along with strong liquor ammonial and soap liniment, is extensively used in the hospital for consumption at Brompton, as a counter irritant. A mixture of tincture of iodine and tincture of opium, as an external application to the spine, is most useful [SPINAL IRRITATION], its use being suspended every three or four days; or a solution of iodide of potass in compound camphor liniment has the advantage of not discolouring the skin or linen.

IODOFORM (C_2HI_3). This compound, which is analogous to chloroform in its constitution, is prepared by adding an alcoholic solution of potash to one of iodine, till the colour of the latter is destroyed; care must be taken to avoid any excess of the alkali; the alcohol is evaporated at a gentle heat, and, as it goes off crystals of iodoform are deposited, which are to be washed with pure water to separate the iodide of potassium.

The properties of iodoform are:—It has the form of yellow brilliant laminæ, which have a slight disagreeable odour, somewhat resembling that of saffron; it is insoluble in water, but very soluble in alcohol, ether, and pyroxylic spirit. It sublimes at 212°, and decomposes at 248°, into carbon, iodine, and hydriodic acid. Its alcoholic solution decomposes very readily.

IODO-PYROMECONIC ACID. [MECONIC ACID.]

IODOQUININE. [CINCHŌNA, ALKALOIDS OF.]

IODOSULPHURIC ACID (SO_2Cl). An acid said to be formed when sulphurous acid is passed into a solution of iodine in pyroxylic spirit. Its existence is problematical.

IONIAN SCHOOL, comprises several of the earliest philosophers of Greece, whose speculations were predominantly of a physiological character, and who, with one or two exceptions, were natives of the Ionian colonies in Asia Minor. From this purely external circumstance the school has derived its name, and its members have been brought into an unbroken connection of masters and disciples by the learned labours of the later Greeks, who strove to give to the first development of philosophy the same orderly transmission of doctrine which prevailed in the later schools. Accordingly Anaximander is made the scholar of Thales and the teacher of Anaximenes, who had two disciples, Diogenes of Apollonia in Crete, and Anaxagoras, whose disciple was Archelaus of Athens, or Miletus, in whom the school closes. Now, not to mention that this purely artificial arrangement omits Heraclitus, the chief of the Ionians, it is also open to great difficulties both of doctrine and chronology. As regards the latter, however, we shall only advert to the general difficulty, that between six and seven generations (212 years) are occupied by the lives of Thales, Anaximander, Anaximenes, and Anaxagoras. The incongruity of the received arrangements appears at once on the slightest consideration of the doctrinal systems of the philosophers of this school. Agreeing in the hypothesis of a primeval state of things, they differed widely in the mode in which they accounted for the deduction of existing phenomena out of the primal substance. One theory endued the universe with life, and considered the orderly procession of all things to be a spontaneous development of a preexistent germ of life. A second accounted for all apparent alteration in the form and qualities of natural bodies by certain changes in the outward relations of space, and proceeded on the supposition of certain permanent material elements which change place in obedience to motion, either originally inherent in or extrinsically impressed on the mass. The latter is the mechanical, the former the dynamical theory of nature. Of the dynamical theorists, Thales first of all taught that all things are pregnant with life; that the seed or germ of vitality, which is in all things, is water, because all seed is moist and humid. Of this potentially living entity Anaximenes advanced a still worthier representation, and taught that the primal substance is infinite and sensuously imperceptible. This principle is analogous to the animal soul, and as the animal soul governs the body, so the universal soul rules and embraces all things. Diogenes made a still farther advance, and maintained that the harmony and design of the mundane fabric suggest the unity and intelligence of its first principle. This principle however he considered as simply physical, and only distinguished from natural phenomena in this, that while it is infinite, as the principle of all, they are finite. Still bolder was the flight of Heraclitus, who taught that the world is an everliving being, a rational fire, whose vitality involves a tendency to contraries, and is ever passing from want to satiety.

The mechanical theory is first opened by Anaximander, who flourished not long after Thales, who conceived the ground both of production and motion to be an eternal substance, which he called the infinite, and wherein the immutable elements were indistinguishably combined. Out of this chaos certain primary contraries, as he conceived them, cold and warm, earth and heaven, were first evolved, and in the course of certain separations and combinations alternately proceeding, more perfect forms are spontaneously developed, to be ultimately resolved into the homogeneous primary. After a long interval of a century Anaxagoras revived the mechanical physiology, and distinctly advanced the principle on which it rests, that nothing is changeable, but that the nature of every thing is permanent. Seizing the contrariety of the moving and the moved, which the mechanical theory is so well calculated to exhibit, he defined the latter to be extended antitypous bulk, inert body, infinitely multiple both in qualities and parts. The moving principle, on the contrary, is perfect, simple, and homogeneous—soul or spirit, which, as moving the elements into combinations of order and beauty, is endued with the faculty of knowing and surveying whatever was, and is, and shall be. Archelaus rather abandoned than advanced the views of his master Anaxagoras, and in him, as the teacher of Socrates, the Ionian school became extinct before the more extensive development of the Socratic philosophy.

(Ritter, *Geschichte d. Ionischen Philosophie*; and Brande's *Geschichte d. Griech.-Röm Philos.*)

IONIC DIALECT, the softest of the four written varieties of the Greek language, was spoken in the Ionian colonies of Asia Minor, and in several of the islands of the Ægean Sea. As the new Ionic, it is distinguished from an older, which was the common origin of itself and the Attic. The old Ionic was widely diffused, and its use was co-extensive with the Ionian settlements in the Peloponneseus and Northern Greece. (Thirlwall, 'History of Greece.') The language of epic poetry arose out of this original tongue, which after the Dorian conquest passed, on the one hand, with the fugitives into Asia Minor, while, on the other, it continued to be spoken, for awhile at least, by the conquered peasantry who remained in Greece Proper. This tradition, which however, like most of the earlier traditions of Greece, is involved in great obscurity, may perhaps serve to explain (what in the common legends of Homer is otherwise inexplicable) the similarity of the language employed by Homer and Hesiod, who, though near to each other in time, were widely separated in the supposed scenes of their poetical labours. This first matured form of the Ionic has been called the epic, and was faithfully adhered to as the standard of Greek epic and elegiac composition by all subsequent writers of epos or elegy, which also owed its birth to Ionians.

On the formation of the new Ionic, or simply the Ionic, great influence was exercised by the commerce of the Ionians, and especially by their intercourse with the soft and effeminate Asiatics. Neglecting the combination of strength with softness which gave to the epic dialect its characteristic fulness of tone, the Ionians attended only to mellowness and euphony, to attain which they softened the aspirates, accumulated vowels, and laid aside every broader and harsher sound. Herodotus (i. 142) distinguishes four varieties (*χαρακτῆρες γλώσσης*) of the new Ionic, in one of which he wrote, and, though a Dorian, has left us the best and most complete specimen of it.

IONIC ORDER. [COLUMN; GRECIAN ARCHITECTURE.]

IPECACUANHA is an emetic substance, the root of several plants growing in South America. All the kinds have nearly the same ingredients, but differ in the amount of the active principle which they respectively contain, termed emetina. The best is the annulated, yielded by the *Cephaëlis ipecacuanha*, a small shrubby plant, native of Brazil and of New Grenada. Of this sort there are three varieties, namely, the brown, red, and gray, or gray-white, called also greater annulated ipecacuan. As this is the only sort sent from Rio Janeiro, it is sometimes called Brazilian or Lisbon ipecacuan. It is sent in bales, barrels, bags, and serons. The root is in pieces from two to six inches long, and about the thickness of a straw, much bent or twisted, either simple or branched, with a remarkably knotty character, owing to numerous circular depressions or clefts, which give the whole an appearance of a number of rings; and hence the term annulated. It consists of a central axis called *meditullium*, and an external portion, called the *cortical* part. One hundred parts of good ipecacuanha consists of 80 parts of cortex and 20 of meditullium. Each contains emetina; but by far the greater portion exists in the cortical. Of the three varieties of annulated ipecacuanha the Brown contains 16 per cent. of emetina, while the red contains only 14 per cent.; the gray has not been analysed.

Another sort of ipecacuan is obtained from the *Psychotria emetica*, called striated; this kind contains only 9 per cent. of emetina, and the undulated or amylaceous ipecacuan, the produce of the *Richardsonia scabra*, holds only 6 per cent. of emetina, with 92 per cent. of starch. Besides these, the roots of numerous other plants are used in tropical countries as emetics, and often termed ipecacuan.

The dust or powder of ipecacuan applied to any mucous surface causes irritation and increased secretion from the part. It is chiefly employed to excite the stomach either to augmented secretion or to invert its action, and effect vomiting. It is also capable, by being combined with other substances, of being directed to the skin, and producing increased perspiration. When given in very small doses, it improves the appetite and digestive powers; in a somewhat larger dose, it acts on the intestines; but in a still larger, it inverts the action of the stomach, and occasions vomiting. It may therefore be used in a great many diseases, such as indigestion, dysentery, rheumatism, common colds, croup, &c. [Emeta; Emetics; Diaphoretics; Antidotes.]

Some caution is requisite in using it, especially with children, as it has a great tendency to produce sleep, and deep depression sometimes follows its use. When an emetic action is required, powder having a nauseous odour is preferable,; when a diaphoretic action is desired, as at the commencement of a common cold, ten or fifeen drops of ipecacuan wine are proper, out of any mild warm drink.

In case of violent vomiting from an over-dose, infusion of strong tea or oak bark may be given, and a mustard poultice applied to each side of the neck.

IPECUANIC ACID ($C_{28}H_{18}O_{14}$?). An acid of doubtful composition, found in the root of the *Cephaëlis ipecacuanha*. It is amorphous, red-brown, and very bitter. It gives a green colouration with persalts of iron, and a violet-black with ammonia.

IPOMÆA PURGA. [Jalap.]

IPOMIC ACID. [Sebacic Acid.]

IRIDESCENCE. A term applied to those brilliant colours which appear on substances presented in very thin plates, such as the soap-bubble, the laminæ of mother-of-pearl, &c. [Interference.]

IRIDIOCYANOGEN (IrC_4N_2) is a hypothetical compound radical. It forms with hydrogen iridiocyanic acid or hydroiridiocyanic acid, and with potassium an iridiocyanide of potassium. The latter occurs in the form of colourless crystals, and gives a deep indigo blue with the salts of peroxide of iron. This is one of the many compounds of a metal with cyanogen, like ferrocyanogen, and which have all the power of combining with other metals possessed by that body. Thus there are cobaltocyanogen, chromocyanogen, platinocyanogen, &c. [Cyanogen.]

IRIDIUM (Ir). An elementary metal occurring in certain ores of platinum. [Platinum, in Nat. Hist. Div.] It was discovered in 1804 by Tennant, but has since been more minutely examined by MM. Deville and Debray. The following is the method recommended by those chemists for the extraction of iridium from the other metals with which in nature it is always associated. The impure chloroiridiate of ammonia obtained in the preparation of the metal ruthenium [Ruthenium] is dried and calcined, and the resulting powder subjected to a stream of hydrogen, whereby all traces of chlorine and oxygen are removed. Platinum and some osmium are now extracted by aqua regia, and ruthenium separated by fusion with nitre and caustic potash, the alkaline salts being dissolved out by water. Any osmium that remains may be dissipated by the oxidising flame of the blowpipe, and the pure iridium fused in the oxyhydrogen lime furnace.

The colour of iridium is pure white, somewhat resembling polished steel. At the ordinary temperature it is scarcely malleable, but at a bright white heat it is perfectly so. The specific gravity of iridium is 21·15; its equivalent, 98·56. In the pure state it is unacted upon by acids.

Iridium and oxygen combine in three different proportions forming

Protoxide of iridium	IrO
Sesquioxide of iridium	Ir_2O_3
Binoxide of iridium	IrO_2

The *protoxide* is a black powder obtained on decomposing the dry protochloride with solution of potash. It is difficultly soluble in acids, but is rapidly attacked by alkalies. The *sesquioxide* is formed when the finely divided metal is ignited in a current of air; it is a bluish-black powder. The *binoxide* is, according to Clauss, always precipitated as an indigo-coloured hydrate when either of the chlorides of iridium is boiled with an alkali.

Iridium and sulphur form combinations corresponding to the oxides, and may be obtained by passing sulphuretted hydrogen through solutions of the respective oxides in acids. The *protosulphide* (IrS) is yellowish brown, the *sesquisulphide* (Ir_2S_3) brown-black, the *bisulphide* (IrS_2), like the protosulphide, but darker.

Iridium and chlorine form three compounds:—

Protochloride of iridium.—($IrCl$) is formed on passing chlorine gas over finely divided iridium heated to incipient redness. It is a dark olive-green powder, insoluble in water, and but sparingly soluble in acids, but when fused with potash and the resulting oxide dissolved in hydrochloric acid and evaporated to dryness, the protochloride remains as a transparent yellow mass readily soluble in hot water.

Sesquichloride of iridium sublimes when the finely divided metal is strongly ignited in a current of chlorine. In this state it is insoluble in water, but when prepared by oxidising iridium with fused nitre, and digesting the residue in hydrochloric acid, then forms with water a red-brown solution.

Bichloride of iridium ($IrCl_2$) results when chlorine gas is passed through water in which chloro-iridiate of ammonia is diffused. With alkaline and other salts bichloride of iridium forms double salts corresponding in composition to the analogous platinum compounds.

Iridium and carbon. When metallic iridium is held in the flame of a spirit lamp, a soft, dark gray powder forms on its surface, owing to the penetration of carbon from the spirit into the metal.

Iridium forms combinations with *phosphorus* and *iodine;* its oxides also form *salts* with some oxygen acids, but the resulting compounds have been little studied.

Iridium-black, having qualities very similar to platinum-black, is precipitated on boiling an alcoholic solution of bisulphate of iridium.

The *alloys of iridium* produced in a well fused state by the employment of the oxyhydrogen lime furnace described by MM. Deville and Debray ('Annales de Chimie et de Physique' for August, 1859) possess properties that render them exceedingly valuable in the arts. Thus the platinum alloy, containing 21·3 per cent. of iridium, is perfectly malleable, and may be worked into vessels possessing greater rigidity than if constructed of platinum alone. Such vessels, moreover, are quite unacted upon by acids, and the operation of dissolving platinum in aqua regia may be conducted in them without risk of their surface being acted upon.

The *derivation* of the word Iridium is from *Iris*, the rainbow, being suggested by the many tints assumed by solutions of the oxides of this metal.

IRIDIUM-BLACK. [Iridium.]

IRIS. [Rainbow.]

IRI'TIS is an inflammation of the iris, the membrane that surrounds the pupil of the eye. [Eye, in Nat. Hist. Div.] It most frequently originates in a disordered state of the system, as in gout or syphilis, but it sometimes follows the exposure of the eye to an intense light, or is produced by external injury, as the wound which is made in the operation for cataract, &c.

Iritis is principally characterised by an effusion of lymph, both into the subetance of the membrane, producing a peculiar dullness of its colour, and on its surface in the form of small masses which adhere at the edge of and around the pupil. The eye is at the same time irritable to light, and the pupil is closely contracted; there is redness of the conjunctiva, and a zone of a bright pink colour is usually seen surrounding the margin of the cornea.

Iritis is very likely to end in adhesions of the iris to the adjacent parts, by the lymph which is deposited upon it becoming organised, and having its vessels united with theirs; in which case, irregularity in the form of the pupil, a loss of its power of contracting and dilating, or even its complete closure and obliteration, with corresponding degrees of obscurity of vision or total blindness, may ensue. These results may be produced in a few days; and the treatment must therefore be prompt and vigorous. Blood should be drawn by cupping or leeches from the head or neck; mercury is usually administered in frequent and full doses till salivation is produced, and belladonna should be applied to or around the eye, to produce dilatation of the pupil and thus prevent its being closed.

IRON, *Medical Properties of.* Iron, in a purely metallic state, does not exert any appreciable influence over the human system. Nevertheless metallic iron is recommended as an antidote to poisoning by the salts of copper. Iron filings have been administered with a view to precipitate the copper in a metallic and therefore innocuous state. White of egg is a more prompt and generally more accessible antidote. The employment of iron filings to absorb fœtid exhalations from the feet is less beneficial than that of recently prepared and freshly powdered charcoal, put every morning into the shoes of those afflicted with this annoyance. Iron filings are sometimes prescribed medicinally, but before any marked effect can be produced by them, the metal must become an oxide or a salt; the presence of any acid in the stomach or alimentary canal promotes this change, while alkalies retard it. This form has been adopted in the treatment of worms, chiefly from the notion that the worms would be annoyed and dislodged by the mechanical irritation of particles of iron. This is an erroneous view. [Anthelmintics.] Tincture of sesquichloride of iron in infusion of quassia is extremely beneficial in all cases of worms, but its efficiency depends on its tonic and astringent properties.

A few only of the preparations and uses of iron can be given here. Sesquioxide of iron (rust, or the subcarbonate of some pharmacopœias), has been given in tic douloureux, in very large doses; in some instances with success. It is likewise useful in some cases of spasmodic contractions of the joints. The very large doses in which it is required to be given is a serious impediment to its use; for not only are the patients averse to it, but it clogs the intestines, which require to be frequently cleared out by a brisk cathartic. It is less objected to when given in London porter, a very suitable vehicle.

The black oxide is not so liable to objection, as it is more readily soluble in the fluids of the alimentary canal.

Ammonio-chloride of iron possesses no advantage over the simple chloride; the tincture of which, called tincture of sesquichloride of iron, is extremely valuable as an emmenagogue; it likewise is very beneficial in checking menorrhagia proceeding from relaxation of the uterus. It checks hæmaturia from relaxation of the tissue of the kidneys. In catarrh of the bladder it is very serviceable. In frequently repeated small doses it relaxes spasmodic stricture of the urethra. But the feeling of nausea and sinking which it causes, renders patients averse to its repetition. It acts as a potent astringent when applied externally or to mucous membranes as an injection.

Sulphate of iron can be given in small doses, in pills or otherwise. Its powers are often much heightened by combination with sulphate of quinia. In nervous debility and indigestion this form is valuable.

The potassio-tartrate of iron has less unpleasantness of taste than most of the other preparations of iron, and is therefore more acceptable to children, to whom also the vinum ferri is much prescribed. Both these are nearly superseded by the citrate or ammonio-citrate of iron, which can be given in the form of lozenge or syrup. The latter given in warm water or lemonade is relished by most children. Still the potassio-tartrate has many recommendations.

Iodide of iron is a preparation of great value in strumous disorders.

The same may be said of the phosphate of iron, a preparation formerly in the 'London Pharmacopœia,' and now most unjustly excluded from it. In the phosphatic diathesis of feeble subjects, with a tendency to rickets, it is invaluable. The dose for children is a very few grains, cautiously increased. The numerous preparations of iron recently introduced by chemists have not been sufficiently tried to permit them to be spoken of with certainty; but in many cases their utility is obvious. Of these the chief are citrate of iron, potassio-citrate, sodio-citrate, zinco-citrate, magnesio-citrate, ferro-citrate, and citrate of quinine and iron; this last is of great service in tic douloureux.

A better form is the pyro-phosphate, which is soluble in water, warm or cold; the form of this in pseudo-crystalline scales, is a pyro-phosphate of iron and soda. This along with rhubarb is a most efficacious cure for the headaches of most young females.

The saccharated carbonate of iron has many advantages. It may quite supersede the well-known Griffith's mixture. Hydrated proto-sulphuret of iron is stated to be an antidote to poisoning by corrosive sublimate, but to be of use it must be given within ten minutes after the poison has been taken. White of egg is a better antidote.

Chalybeate waters often furnish the best medium for administering iron; especially when the iron is associated with much free carbonic acid. Where no free carbonic acid is present, and in some instances even where it exists, the water of the springs should be received in and drunk out of *warm* water. This often prevents the spasm which is apt to occur when very cold water is suddenly taken into the stomach.

Besides being reputed an antidote to the poisonous salts of copper, iron is asserted to prove an antidote to other violent poisons.

Hydrate of peroxide of iron, called also hydrated peroxide of iron, is considered a trustworthy antidote against arsenic, if administered promptly, while the arsenic is yet in the stomach, and not absorbed. Prussic acid may be decomposed or combined, so as to be rendered innocuous, by giving promptly, first, solution of carbonate of potass, followed by a very diluted solution of the proto-persulphate of iron; the object being to form a ferro-prussiate of potass in the stomach. (See 'Lancet,' 5th October, 1844; or 'Pharmaceutical Journal,' vol. iv. p. 373.)

Physiological Effects and Therapeutic Employment of Iron.—Iron exists both in plants and many animals, as the mammiferæ and birds, constituting an essential part of their fluids and solids; but, incorporated as it is thoroughly with them, it gives rise to none of those phenomena which it occasions when taken into the stomach. Upon the living tissues iron has a tonic influence; and as its preparations greatly promote digestion, they excite the appetite and render more easy the elaboration of the aliment. The vitality of the digestive organs being exalted, they extract from the food more of the nutritious principles, and thereby furnish a greater quantity fit to be assimilated.

These beneficial effects are best seen when the medicine is given in small and long-continued doses, or in the greatly diluted state in which iron occurs in the mineral waters or chalybeate springs. On the other hand, chalybeates occasion at times, especially if in large doses, pain of the epigastre, nausea, fœtid eructations, and great anxiety; consequences referable to the immediate impression, a sort of constrictive action, which the preparations of iron make or exercise when they reach the stomach, upon its internal surface, and the nerves which are distributed upon it. The unpleasant effects may generally be avoided by giving it at first in very small doses, gradually increased, or by diluting it with some vegetable substance of little activity.

Iron given in large doses, when it reaches the intestines, produces in some persons obstinate constipation, accompanied with a sense of great heat in the lower belly; in others it occasions colics and frequent alvine dejections; while with a third set of persons none of these effects follow its administration.

During the use of iron the fæces invariably become blackened, which is caused by the tannin of our food acting upon the iron.

In respect to the secondary effects of iron, the amount of these depends upon the quantity absorbed, and the length of time it has been given. That it is absorbed, in most instances, and carried into the circulation, is proved both by the effects of it being felt over the whole system, and by being distinctly recognisable in the urine on the addition of an infusion of galls. When used for some time, chalybeates increase greatly the power of the heart; the pulse becomes stronger and harder—effects most observable upon persons previously enfeebled by disease. If persisted in, they cause increased arterial action, followed by febrile commotion, sense of heat, and hæmorrhagic discharges from different parts of the body. These phenomena show themselves most speedily in persons of a plethoric habit and sanguine temperament; iron also rouses the absorbent organs when sluggish.

The functions of nutrition and assimilation are greatly heightened by the use of iron; but if it be too long persevered in, diseases of over-action ensue, as inflammations, hæmorrhages, &c. These symptoms indicate the necessity of discontinuing it.

The preparations of iron are unquestionably efficacious in diseases which proceed from a relaxation of the substance of the living tissues, from an inactivity of the reparative or assimilative function, or in case of weakness proceeding from deficient supply of nervous energy.

Hence they are indicated in anæmia, in convalescence from debilitating fevers, and other tedious diseases, as well as after some of the more acute phlegmasiæ, as pneumonia, the cough remaining after which, if not occasioned by any organic change, is sooner removed by preparations of iron or bark than any other means. Chalybeates are likewise given in defective menstruation from debility of the uterus, and sometimes in sterility. In chlorosis iron is almost our sheet-anchor, while it is also very serviceable in some forms of dyspepsia, also in worms, (in which the sulph.-ferri is given in large doses), in passive hæmorrhages, and it is prescribed empirically in many of the cachexiæ, as scrofula.

Chalybeates are found useful in many nervous diseases, as hysteria: the cough which is often present in these complaints may be effectually removed by preparations of iron. The indurations, too, of the mammæ (apt to be considered of a cancerous nature), and of other glands in hysterical females, are often dispersed by the use of iron. Some of the forms of tic douloureux, not dependent upon organic causes, are often cured by chalybeates. Iron has likewise been prescribed in the intervals of the paroxysms of intermittents, particularly quartans. The sulphate is given in the dose of ʒi. in a pint of water,—in which circumstance it can only act beneficially, like cinchona or bitter tonics,—iron being among minerals what bitter herbs are among vegetable remedies.

Chalybeates are *contra*-indicated in plethora and all inflammatory diseases, as well as active hæmorrhages, as also during pregnancy in females of a sanguine temperament.

IRON MANUFACTURE AND TRADE. The art of smelting iron was practised in this country during the time of the Roman occupation. The principal seats of the manufacture appear to have been Sussex and the Forest of Dean, or Arden as it was then called. It is known that iron-works existed in that part of Gloucestershire in 1238; because there occurs among the patent rolls of Henry III. of that date, one entitled 'De Forgeis levandis in foresta de Dean.' Remains of ancient iron-furnaces have been noticed in Lancashire, Staffordshire, and Yorkshire. The art of working in iron and steel was much practised in this island before the Norman conquest. We are told that not only was the army of Harold well supplied with weapons of steel and with defensive armour, but that the horses were covered with steel and iron armour, and that every officer of rank maintained a smith, who constantly attended his master to the wars, and took charge of his arms and armour to keep them in proper repair.

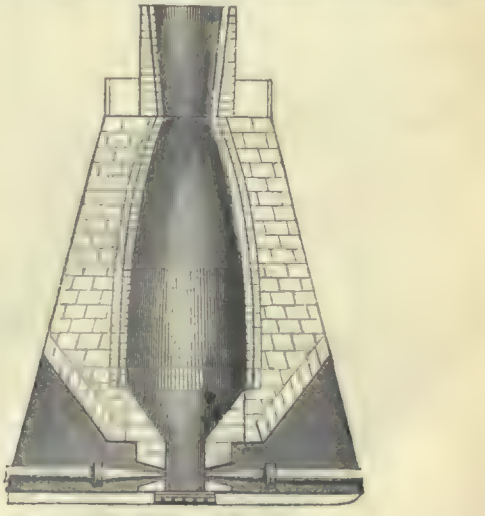
Fig. 1.—Vertical Section of Blast Furnace.

There are three principal qualities into which this metal is commonly divided, namely, pig-iron, cast-iron, and malleable or bar-iron, the second and third being the results of an extension of the processes necessary for the production of the first.

Pig-iron.—The first process is that of reducing the iron-stone or ore, or, as it is technically called, the *mine*, into a metallic state by means of fusion. This operation is conducted in a *blast-furnace*, the form and construction of which will be understood from the following section. The interior of this furnace in the broadest part, which is called the *boshes*, is usually from 14 to 17 feet in diameter, and this is gradually decreased to about half that diameter at the top. The whole is built of masonry, the lining to the furnace being composed of fire-bricks carefully jointed together with fire-clay: the whole furnace is strongly bound together with iron hoops or stays. The furnace is again contracted below the boshes, and into this lower part the melted iron falls as it is formed. The ground-plan of this lower part of the furnace is constructed as shown in the following diagram, where the unshaded square in the centre represents the *hearth*, and is about 3 feet square. The three tubes leading to this hearth (two of which are shown in the vertical section), and which are called *tuyeres*, are used for introducing the blast of air required to give the degree of intenseness to the heat necessary for fusing the ore.

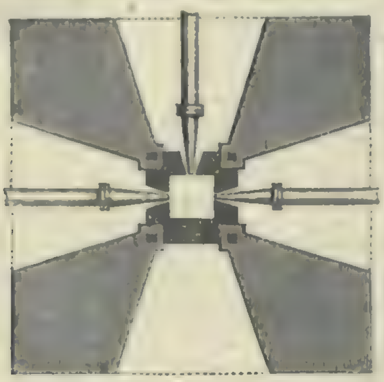

Fig. 2.—Ground Plan of Blast Furnace.

The size and form of the blast furnaces have undergone much change. Slight differences will be observed by comparing the section in *fig.* 1, with that at col. 241 of the article FURNACE; but the modern alterations have been still more considerable. Half a century ago the furnaces were generally about 40 feet high, 10 or 12 feet across the boshes, and 3½ feet diameter of tunnel-head, or cylinder, at the top; and they were blown with only one tuyere each. By degrees the tunnel-head has been enlarged to 10 feet; the tuyeres have been increased from one to three; a new form has been given to the lower part of the interior; and in some instances, such as that of Messrs. Dixon's works at Govan, near Glasgow, the whole furnace is made cylindrical. The largest furnaces are now 60 feet high, and about 40 feet square at the base. Engineers are still divided in opinion concerning the best size of the *throat*, or contracted part between the body of the furnace and the tunnel-head; but all agree that it should be much longer than those formerly employed.

We have now to notice the filling of the furnace with iron-ore, coke, and limestone. The ore must previously have been roasted or calcined in a kiln, in order to drive off the water, sulphur, and arsenic, with which it is more or less combined in its native state: by this process it loses one-sixth part of its weight. One of the recipes for smelting iron, in use a few years ago, gave the proportion at 15 tons of roasted iron-ore, 22½ tons of coke, and about 6 tons of limestone; but these proportions vary according to the quality of the ingredients, and the routine of processes. The ingredients are supplied at equidistant charges, and must be intimately mixed together in the furnace. The limestone must be broken into small pieces; its use is to act as a flux to the ore and promote its fusion. The mode of filling the furnace varies a good deal. In Wales, the blast furnaces are usually built on the slopes of hills, so that the minerals can easily be brought from the mines to the top of the furnace; but where the latter is built on the level of the ground, as in most of the midland districts, the minerals must be raised to the proper level by steam, water, or pneumatic power. Inclined planes have generally been used; but these are in many works being superseded by a direct vertical lift. One of the filling-mouths at the top of a furnace (of which there are sometimes four) is shown in *fig.* 3. The usual plan is to throw in the ore, coal, and limestone in alternate barrowsful; but Mr. Slate, in 1859, proposed a new method. He makes the furnace-mouth very wide, and places over it a bridge supported by iron girders. A cast-iron pipe descends vertically from the bridge into the furnace, and is continued down beneath the surface of the burning material; the greater portion of the fuel is fed in through this pipe; while the other materials are fed in through the open mouth of the furnace; insomuch that the fuel is always in the middle, and the ore and flux around it. A valve lifts up the cover of the central pipe; and several scuttles or openings are left to admit the other materials. How far the cast-iron pipe will bear the intense heat, is a point not yet satisfactorily determined.

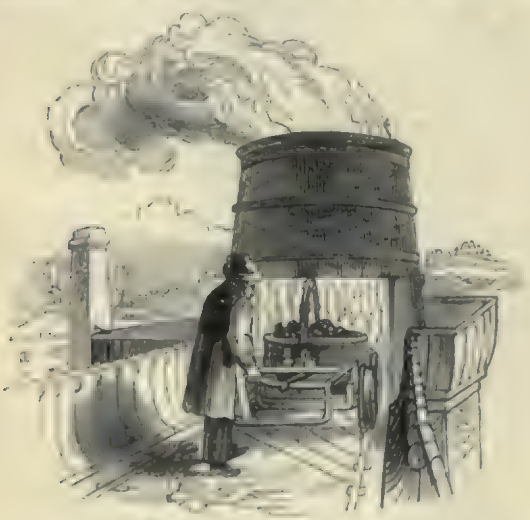

Fig. 3.—Filling Blast Furnace.

Supposing the fire to be lighted and the minerals introduced, the next matter is the important one of the *blast*. The heat that would be produced in any furnace by merely setting fire to the fuel which is thrown into it would be altogether insufficient for the fusion of the ore, if its intensity were not promoted by the forcing in of a current or blast of air. For this purpose it is necessary to use a strong mechanical force. Water-wheels, where they can be had, are suitable agents; but there are not many places where a sufficiently copious and regular supply of water at all seasons can be commanded, and the success of an iron-work would be destroyed by the failure of the blast in any degree for even a short time. Steam-engines are now, therefore, almost universally preferred. This power is applied to the working of a blowing cylinder, which may be many times the area of the cylinder of the steam-engine. If the blast thus produced were passed immediately from the blowing cylinder through the tuyeres to the furnace, the effect would be intermitting and irregular, ceasing at the end of each stroke of the steam-piston. To remedy this inconvenience the blast is carried into an intermediate chamber of a spherical or cylindrical shape, called a regulator; and as the air is in a state of condensation when admitted, its effort to expand itself again to its natural volume causes the continuous and regular supply to the furnace which is necessary. The air thus forced into the furnace keeps the heat at a high degree of intenseness. Until about thirty years ago, the air thus supplied was uniformly at the temperature of the atmosphere from which it was immediately taken; and the effect was not only to produce a stream of cold air, but also to supply a quantity of moisture which is prejudicial to the smelting process. Atmospheric air always contains moisture in some degree or other, but holds a larger proportion in hot than in cold weather, for a very obvious reason, and this causes the furnaces not to work so well in summer as in winter. By the previous drying and heating of the air these inconveniences are remedied, the consumption of fuel is lessened, and the absence of moisture is said to have a beneficial effect upon the quality of the iron produced. This improvement was the invention of Mr. Neilson, of the Clyde iron-works, and was made the subject of a patent in 1829. The air, before it is forced into the furnace, is heated in cast-iron vessels to 300° Fahr., or more, and is thus more nearly than when at its natural temperature in a condition to support combustion.

The precise value of the hot-blast has been a subject of very animated controversy. That it has contributed greatly to the advance of the manufacture is beyond all question; but some persons appear to carry this estimate to too high a degree. Just before Mr. Neilson introduced his method at the Clyde Works, it was customary in that establishment to use eight tons of coal for making one ton of iron; in the next following year the quantity was reduced to five tons and a quarter, with an addition of eight cwt. for heating the air before using. In 1831, Mr. Dixon, of Calder Works, found that if the temperature of the blast were raised far above 300° Fahr., raw coal might be used instead of coke in the blast furnace—a most important discovery, for it rendered unnecessary the cost of time and money in coking the coal for making certain descriptions of iron. From that time it became usual to raise the blast to 600° Fahr., about sufficient to melt lead or zinc. In 1833, it was asserted that three tons of coal sufficed, including that for heating the air, for smelting one ton of iron; and that the same quantity of air would blow four furnaces as had previously been used for three. The hot-blast has from the first been more favoured in Scotland than in Wales or in Staffordshire; nevertheless it is increasing everywhere in use. Mr. Truran takes exception to some of Mr. Mushet's statements concerning the enormous saving effected by using the hot-blast. He contends that only a part of the economy now unquestionably observed in the manufacture is due to this cause, the rest being traceable to other improvements. He shows this by adducing the important fact that furnaces, in which the hot-blast has never been employed, continue to increase their produce. This has been especially observable at the great Dowlais Works, near Merthyr Tydvil, where the economising of fuel has been very great without any change in the temperature of the blast. Mr. Truran attributes these improvements partly to an increased use of carbonaceous ironstone, and partly to an enlargement in the throat of the furnace, which facilitates the use of raw coal as a substitute for coke. At the Plymouth and Duffryn Works, one in Glamorganshire and the other in Monmouthshire, the yield has gradually increased to 130 tons of pig-iron per week, from an average of much less than half that quantity, without any departure from the old cold-blast. Some of the steam-engines now employed to send the blast into the furnaces are quite stupendous. The blowing cylinder of the engine at the Dowlais Works is 144 inches in diameter, and makes 19 strokes per minute, with a length of stroke of 12 feet: it sends in 50,000 cubic feet of air per minute, at a pressure of 3 lb. on the square inch; and its boiler-furnaces consume a ton of coal per *hour* to raise the necessary steam.

The blast, whether hot or cold, having done its work, the metal contained in the ore has become liquefied, and is then ready for removal. The iron is run from the furnace every twelve hours, by tapping it in the front, on a level with the bottom of the hearth, at the side on which, as will be seen from the diagram, there is no tuyere introduced. When the furnace is tapped, the metal is allowed to run into channels formed in the sand of the smelting-house floor. The names of *sow-metal* and *pig-metal*, which were originally given by the workmen, signify in one case the blocks of iron which are formed in the large main channels, and in the other case the smaller blocks which are formed in smaller side channels communicating with the larger ones; these names were adopted from the fancied resemblance of the cast metal to a sow and her litter of pigs. This is iron in its crudest state. The weight of materials lost in its production is somewhat greater than that of the fuel used; taking into account the refuse cinder and ashes with the metal, the whole does not weigh quite so much as the ore and lime that have been put into the furnace. Large heaps of cinder are gradually accumulating in the neighbourhood of iron-works, and give a dreary aspect to the country.

The quality of pig-iron varies according to the purposes for which it is intended, and depends not only upon the quality of the ore, but also upon that of the fuel. The principal division is into *foundry-iron* and *forge-iron*, the former being used for castings, the latter for conversion into malleable iron. Foundry-iron is further divided into three qualities, distinguished by the numbers 1, 2, and 3. No. 1 contains a large proportion of carbon, which it has acquired from the coke used in smelting, and the quality of which has been chosen with a view to the production of this kind of iron; it is soft and very fluid when melted, so that it will run into the finest and most delicate forms the moulder can produce. No. 2 contains a smaller proportion of carbon; it is harder than No. 1, closer grained, and of more regular fracture; it is more refractory in the furnace, and does not run so freely when melted as No. 1; but as it is harder and stronger, it is preferred for purposes where strength and durability are required in preference to delicacy of form: these two kinds are unfit for conversion into bar-iron. No. 3 varies in the same direction as No. 2, but in a greater degree, from the qualities of No. 1; it is used for many kinds of heavy work, where it has to bear great strains and is exposed to constant wear. Forge-iron is divided also into three qualities, and is distinguished as *bright-iron*, *mottled-iron*, and *white-iron*, which names are indicative of the appearance each quality presents to the eye. They all of them contain some carbon, but less than foundry-iron, and in proportions diminishing in the order in which they are here mentioned, white-iron having the smallest proportion of any, and being exceedingly hard; its fluidity too is so small that it runs with difficulty into the channels provided to receive it at the first smelting, and it is altogether incapable of being afterwards used for foundry purposes.

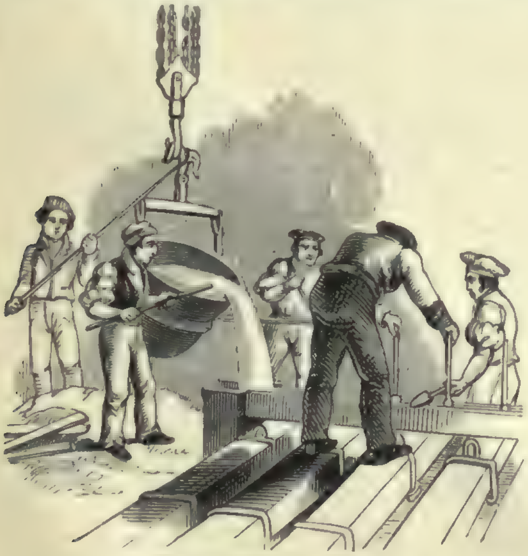

Fig. 4.—Casting Iron Pipes.

Cast Iron.—Of casting or founding we need not speak here; it has been sufficiently noticed under Founding, and under other headings cited in that article. One of the modes of casting iron-pipes is shown in *fig.* 4.

Malleable-iron.—This, which is also called *forge-* or *bar-iron*, is pig-iron freed from carbon and oxygen. The first operation for producing this change is called *refining*. It is performed in small low furnaces about three feet square at the base, having the bottom or hearth of fire-bricks, and the sides of cast-iron, made hollow to allow a stream of water to pass constantly through, which prevents their being quickly burnt away; near the top are holes for the insertion of blast-pipes. These refineries have iron doors at the back, but are open in front; the whole is surmounted by a chimney of brick-work carried to the height of 20 feet from the ground. At the level of the hearth in front is a hole similar to that in the smelting-furnace for running out the melted metal. This communicates with a flat mould of cast-iron 20 feet long and 2 feet wide, placed over a cistern of water with which its under surface is in contact, and which serves to cool the metal rapidly as it runs into the mould. The iron is kept in a state of fusion in the refinery for some time, exposed to an intense heat produced by a strong blast. From the sudden cooling to which it is exposed, the plate when run into the mould is very brittle: when broken the fracture presents a bright silvery appearance. From 22 to 23 cwt. of pig-iron is required to produce one ton of refined iron, and from 10 to 12 cwt. of coke is used for the purpose.

The iron being refined, the next process employed for making bars is called *puddling*, and is performed in a reverberatory furnace, thence called a *puddling-furnace*. The structure of this furnace will be explained by *fig.* 5. In this diagram *a* is the grate, which is supplied with coal through a door in the side. The refined metal broken in small fragments is placed in the body of the furnace *b*, over which the flame is made to play in its passage to the chimney, *c*. The degree of the draft is regulated by a damper on the top of the chimney, which is about 30 feet high. Such is the intenseness of the heat in these furnaces, that when the damper is raised the flame is sometimes carried to the top of the chimney. Compare this cut with one in the article Furnace, col. 240, for a few additional details. The quantity of refined metal put into this puddling-furnace at each charge is from 3½ to 4 cwt. In about half an hour from the charging of the furnace the metal begins to melt. The puddler then observes, through a small hole provided for that purpose and for the introduction of his tools, the progress of the work. The business of the puddler is so to dispose of the pieces of metal, moving them by means of his tools, as to ensure an equable application of heat to the mass. When the whole quantity is fully melted, the puddler stirs the metal about briskly, changing his tools continually that they may not be melted. By means of this agitation the metal gives off an elastic fluid, and after a time becomes thick, and grows increasingly so, until it loses all fluidity and forms into lumps. The contents of the furnace are then divided into five or six portions by the puddler, and each is made up by means of his tools into a roundish form. These balls are technically called *blooms*. Being taken from the puddling-furnace they are subjected each to several blows from a heavy hammer (called shingling), which makes them more compact and gives them a shape more convenient for going through the rollers. The form and construction of these rollers are shown in the following diagram. The bloom is passed in succession through the holes in *a*, beginning with the largest and proceeding to the smallest; or through the grooves in the second roller *b*; and is thus reduced to the requisite width and thickness. By these rollings the iron is converted from a fusible, hard, and brittle substance, to a tough and elastic bar which is hardly fusible, and which from its property of yielding and altering its form under the hammer has acquired the name of *malleable* iron. The quantity of refined metal required to

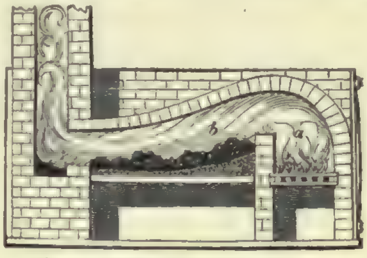

Fig. 5.—Section of Puddling Furnace.

make one ton of these rough bars is about 22 cwt., and the quantity of coal consumed in the process is about 17 cwt.

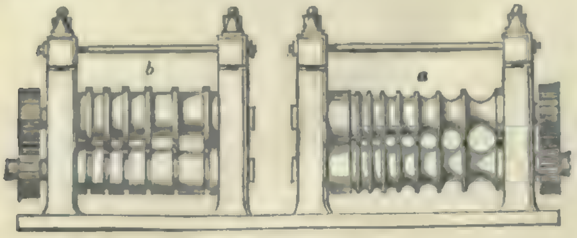

Fig. 6.—Puddling Rollers.

All the processes of refining, puddling, and blooming, like those of smelting, have undergone numerous improvements within the last few years. Refining is always needed for making the best iron; but it is not so much adopted as formerly for the medium kinds. Sometimes, instead of refining and puddling, a process called *boiling* is adopted; and this practice has of late been greatly extended. Those who 'boil their pigs,' as it is termed, do so under the impression that it obviates some of the waste involved in refining. The boiling-furnace differs in some particulars from the others. Into it is put a portion of hammer-slag, then pig-iron, and then fresh coal. The metal is kept almost in a boiling state for half an hour, the puddler working it about all the time; a cinder or heavy slag falls to the bottom, and the gradually-thickening iron is worked about into balls. As generally conducted, the melting occupies about half an hour, the boiling half an hour, and the balling an hour. All the manufacturers admit that refining and puddling produce the best iron; but they differ in opinion concerning the relative advantages of boiling for the middling and cheaper qualities. Boiling is less in favour in South Wales than in Staffordshire. When the iron has been worked about into balls or blooms, either by refining and puddling, or by boiling, the blooms are, as we have said, shingled, or beaten with a few blows of a heavy hammer; this is admitted to make the best iron; but the makers of inferior kinds prefer to use a machine called a *squeezer*, because it leaves some of the slag in the metal, and thereby increases the quantity. Mr. Brown, of the Oak Farm Ironworks, has recently introduced a machine for this purpose. Three excentric cams work simultaneously; they are kept rotating in one direction by wheels and pinions, worked by steam power. The convex sides of the cams are grooved and serrated. A bloom of white-hot iron being dropped into the concavity of the upper cam, it is drawn into the centre of motion of the three cams; the convexities approach nearer and nearer, and the serrations squeeze and knead the iron like dough. The slag and impurities are expelled, more or less completely, and fall out of the machine. By the approximation of the cams, the iron is sent out as a sort of cylinder. This may be the best place to notice a plan brought forward by Mr. Maudslay, in 1858, for producing cast-iron possessing a degree of toughness almost equal to that of the best wrought iron for the steam-engine manufacture. The plan consists in the employment of an entirely novel furnace, which revolves on an axis inclined about 10° from the perpendicular. The rotation is maintained by a system of gearing and toothed wheels, actuated by steam power. The iron being brought into a molten state in the furnace, and being kept constantly stirred, the two movements of rotation and stirring afford great opportunity for the sulphur and other impurities to escape from the mass and to fly off. The iron becomes semi-puddled; it retains a sufficient degree of fluidity to be cast into moulds, which fully puddled iron does not; while it has more fibre and toughness than pig or raw iron. The metal is, in fact, precisely in a medium state between pig-iron and malleable-iron.

Rolled Iron.—We shall adopt this as a convenient name for iron in a more advanced state. We have seen that the crude smelted metal constitutes *pig-iron;* that when this is run into moulds it becomes *cast-iron;* and that when the pigs have been refined and puddled, or boiled, the result is *malleable-iron.* This malleable iron is the substance from which are made bars, rails, nail-rods, wire, sheets, &c., all of which we may consider to be varieties of rolled iron, since they all pass between the nearly touching surfaces of ponderous iron-rollers.

When the blooms have been shingled or squeezed, and roughly rolled into bars, in the manner already described, and while yet hot, they are cut into convenient lengths and taken to the *balling-furnace*, the shape and construction of which resemble the puddling-furnace. In this balling-furnace the bars are piled evenly, so that one bar does not project beyond another. Several of these piles, each of which is composed of five or six bars, are placed at once in the furnace, and when sufficiently heated, so that they will weld together, the piles are taken out separately and are passed again through rollers similar in construction to those described above, but differing from each other in the form of their orifices and grooves, so that either round or flat or square rods and bars may be produced at the pleasure of the maker.

In the production of various kinds of iron from the malleable state, little more is necessary than to vary the rollers through which the iron passes, in their diameter, their power, their closeness, or the size and shape of their grooves. In some of the establishments, the roughing-rolls, or those first used, are of vast size and weight—as much as 6¼ feet long by 22 inches in diameter, requiring great steam-power to rotate them. Some of the achievements in rolling bars are very remarkable. When the Great Exhibition of 1851 was about to be held, the Rhymney Works in Monmouthshire produced the largest and heaviest rail ever made, being 52 feet long and weighing 1575 lbs. Thereupon, the workmen at the Tredegar Works voluntarily undertook, for the honour of their firm and not for pay, to produce a still larger rail; their specimen was 60 feet long, but a few pounds lighter than that from Rhymney. The rolling of iron into rails, bars, and rods is very similar in its character, seeing that there are grooves in the rollers for all these kinds. In producing sheet-iron, however, this is not the case; the rolls are smooth, and the gradual thinning of the sheet results from bringing the rollers more and more closely into contact. In preparing the sheets for various manufacturing purposes, a machine is sometimes used, one end of which cuts the iron as if it were a piece of pasteboard, while the other pierces it for the reception of rivets.

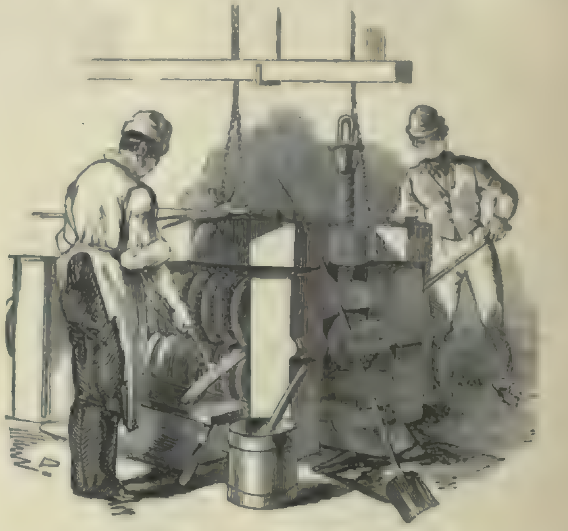

Fig. 7.—Rolling Bar-iron.

It is right to mention here, that the rolling of iron was one of the capital inventions of Richard Cort, who, by a series of scandalous actions on the part of a government officer, and laxity in official morality generally, was brought to utter ruin in the attempt to carry out a system which has greatly enriched the iron manufacturers of this country. The whole case is being minutely narrated by Mr. Webster, the barrister, in a series of papers in the 'Mechanics' Magazine' for 1859 and 1860.

Projected Improvements.—It is impossible to notice here all the novelties introduced or proposed in the iron manufacture within the last few years; but there are three concerning which a few words may be given: namely—the production of iron direct from the ore; the utilisation of slag; and the utilisation of the gases and heated air of the blast-furnace. The process introduced and warmly advocated by Mr. Bessemer will best be noticed in connection with STEEL MANUFACTURE.

The making of wrought-iron direct from the ore is now attracting much attention in the United States. The iron is in this case not puddled, as it never melts; but having first been deoxidised in a close chamber, it is simply welded together. There are many patented processes at work to this end. In one, Kenton's, the surplus heat from the reducing chamber passes round a series of tubes where the other processes are going on, insomuch that one mass of fuel avails for the whole operation. Another, Davis's, begins by pulverising the ore, mixing it with 20 per cent. of coal, putting the mixture into an air-chamber heated by anthracite, and thence passing it to a sort of puddling-furnace heated by the same fuel. A third, Harvey's, employs the gases generated in the furnace to act directly on the ore in deoxidising and desulphurising it, without making the puddling process a distinct one. The object of all these plans seems to be to save fuel and labour; but English manufacturers have not yet seen reason to place much reliance on the methods.

The utilisation of slag is an important matter, if practicable; for there are millions of tons of it lying waste, all of which is known to contain a certain per-centage of iron. Professor Bleekrode, in a communication to the Society of Arts in 1859, drew attention to this matter. Of the vast heaps of slag now existing some are modern, while some are the remains from ancient works. The Swedes make good iron from the slag of their old charcoal smelt-works, in a furnace suggested by Sefström in 1821. At Liege slag is mixed with the poorer ores, and smelted. The Silesian slag has been utilised since 1855, by mixing it with a certain per-centage of argillaceous schist and limestone. The same thing is done in Austria. The slag of the Dean Forest Works used to be made into a peculiar kind of black bottles at Bristol. Numerous processes have been patented in England within the last few years for rendering the slag useful, generally by mixing it with lime or limestone. Dr. Percy has recently observed: "An immense quantity of iron slag, far richer than many iron ores, is annually thrown away. It may be that the presence of phosphorus in sensible quantity is one of the causes which prevent the re-smelting of this slag with advantage. This fact has not yet sufficiently attracted the attention of those engaged in the manufacture of iron. The discovery of a method of extracting economically good iron from these rich slags would be of great advantage to the country, and could not fail amply to reward its author." Among the *seven million tons* of slag supposed to be annually produced in this country, many specimens are very beautiful when cast into moulds, looking like marble and serpentine when polished. Hence have arisen certain plans of utilisation, irrespective of the re-smelting for the sake of the metal. But there are drawbacks. If exposed to the air, the slag becomes oxidised and rusted; if not well annealed, it becomes friable; if in every way well prepared, it takes so much labour and fuel to work it that it ceases to be a commercially profitable material.

The third subject, the utilisation of waste heat, was taken up a few years ago by the Ebbw Vale Iron Company of South Wales. After a furnace has performed the work for which it is intended, various gases escape with the smoke, at the upper orifice; and these gases carry with them a large amount of valuable heat. If the heat could be abstracted and usefully applied, without lessening the power of the furnace, an economical benefit would result. The above-named company had eleven blast-furnaces, five engines to produce the blast, and twenty-five boilers to supply the engines with steam. The greater number of these boilers were wholly heated by the waste heat from the blast-furnaces; and various ovens and stoves in the works were heated by similar means. The heated gases were arrested near the top of the furnace, carried out by a horizontal tube, mixed with atmospheric air admitted in thin sheets or layers, and ignited by a small fire. It formed a true gas-light; and this gas-light heated a large flue, which was surrounded by a boiler containing water; and thus was a supply of steam obtained. These operations at Ebbw Vale depended on the combustion of the furnace gases; and the Ystalyfera Works modified the process by mixing the gases more thoroughly with atmospheric air. At the iron-works generally, however, it is considered that there are disadvantages which counterbalance the supposed saving; and neither plan has yet been very extensively acted on.

Iron Trade.—The expansion of the iron trade is one of the most remarkable things in the history of our national industry. When charcoal was used for fuel; when there were no steam-engines to force in a blast; when the air employed for the blast was cold; and when there were neither rolling-mills nor shingling-hammers, a large production was impossible. Nor was there such a demand as would make even an approach to that which now exists; for iron bridges, iron ships, iron houses, iron roads, iron pontoons, iron cables, iron articles—from 'Great Easterns' down to shirt-buttons—are things of the present. It is supposed that in 1740, the produce of iron in Great Britain was about 17,000 tons. In 1750, a bill was brought into parliament, in the interest of iron-purchasers, for the importation of iron from the American colonies. This was opposed by the *tanners*, on grounds not very easy to guess *à priori*, but curiously illustrative of the spirit of protection. If, it was argued, colonial iron be admitted, English iron masters would be undersold; if so, some would be ruined and others would leave the trade; if so, many of the furnaces and forges would be put out of blast; if so, less wood would be used for fuel; if so, there would be less oak-bark in the market; and if so, the tanners might suffer from a deficiency of tan-material. Later in the century, however, when improvements and new appliances were numerous, it mattered little whether colonial iron was imported or not; seeing that the home produce would supply all demands. By 1788, the produce reached 68,000 tons; the weekly produce from the blast-furnaces averaged about 20 tons each. By 1796, the produce was 125,000 tons, and the weekly average per furnace 27 tons (taking the celebrated Dowlais works as an exemplar). Approximate estimates made at different times, set down the quantities of pig-iron made at 250,000 tons in 1806, 400,000 tons in 1820, and 690,000 tons in 1827; the average produce per furnace being raised in those same years to about 42, 62, and 70 tons per week, partly by the adoption of larger dimensions in the furnaces themselves, and partly by improved processes.

The introduction of the hot blast by Mr. Neilson in 1829 was shortly followed by a very remarkable extension of the manufacture. The produce of 1836 was about 1,000,000 tons, and the weekly average per furnace about 85 tons. The year 1839 was the first for which any trustworthy statistics were obtained, the estimates for previous years having been little more than guesses. Mr. Mushet, for that year, set down the number of blast-furnaces at 430, of which 377 were at work, producing about 1,250,000 tons in all. Of the furnaces in blast, 135 were in Wales, 188 in England, and 54 in Scotland; Wales had the largest yield per furnace, but England the largest total yield. Soon after this period the Scotch manufacturers made such an enormous extension of the trade, that they quite glutted the market. The large profits led to the building of new furnaces; the discovery of blackband in the Airdrie district increased the available store of cheap raw material; the hot-blast effected a saving in the coking of the fuel; and the Scotch banking system led to the advance of capital almost to a reckless extent. Hence the produce of pig-iron in Scotland, which had been only 37,000 tons in 1830, rose to 197,000 tons in 1839, and 276,000 in 1843. It was especially in 1841 that the Scotch makers glutted the market, at a time when the demand was not brisk; Staffordshire and South Wales suffered severely, for they could not manufacture at a profit, at the prices established by the Airdrie masters. The railway mania of 1844-5, however, revived the trade; the companies not only took all the railway-bars available, but called for so enormous a quantity that new furnaces were needed to supply it. In 1845. Scotland alone made 470,000 tons of iron, of which no less than 234,000 were shipped at the Clyde for England and elsewhere; in 1846 these numbers rose to 522,000 and 277,000 tons respectively. Advancing to the year of the Great Exhibition, we find that Scotland produced in 1851 the vast quantity of 803,000 tons; which was increased to 840,000 in 1853. It had by this time been discovered that Scotland could make raw or pig-iron at a cost only a little exceeding 2*l*. per ton; from 1848 to 1853, the market price varied from 2*l*. to 3*l*.; many of the furnaces being thrown out of blast in the season when the market price only reached, or barely reached, the cost of production. Bar-iron fluctuated much more considerably; for it differs more in quality, and has had a larger amount of labour bestowed upon it, than pig or crude iron; it was sometimes as low as 5*l*. per ton, sometimes as high as 10*l*. Mr. Braithwaite Poole gave an estimate of the iron produce of 1852, for the whole kingdom; from which it appears that there were 497 furnaces in blast, 158 out of blast, and nearly 2,700,000 tons of iron produced—of which England produced 1,190,000, Scotland, 775,000, and Wales 716,000. The authority for this estimate was, however, not given; and so far as Scotland is concerned, it falls short of one given by Mr. Scrivenor.

The most trustworthy statistics of the iron trade of Great Britain, and the latest available in date, are probably those of Mr. Truran, published in his volume on the 'Iron Manufacture.' This engineer was manager of Guest's vast establishment at Dowlais, and afterwards of Crawshay's at Hirwain; and consequently had the best means of acquiring a practical knowledge of the whole subject. His figures refer to 1855. He gives the name of every iron-work in Great Britain; the number of blast-furnaces at each; the weekly power of production at each furnace; and the aggregate power of produce in the year. Avoiding all the minute detail, some of the more general results may be given here, dividing the island into districts for facility of comparison:—

Districts.	No. of Iron Works.	No. of Furnaces.	Weekly Average. tons.	Total Produce. tons.
South Wales	38	169	118	1,042,776
South Wales (anthracite)	11	37	72	139,880
North Wales	9	19	63	62,180
Dean Forest	5	10	94	48,880
Lancashire (charcoal)	4	4	?	4,200
South Staffordshire	65	169	108	950,520
North Staffordshire	7	19	104	102,960
Derbyshire	12	30	101	158,080
Shropshire	14	34	86	151,720
South and West Yorkshire	12	31	72	116,480
North Yorkshire and Durham	23	79	132	541,320
Scotland	37	145	145	1,082,640

These figures present much which is worthy of notice. The total producing power in 1855 was about 4,400,000 tons, made in 746 blast furnaces at 227 iron works; presenting an average weekly producing power of 113 tons per furnace. The shares of produce were, in round numbers, England 2,080,000; Wales 1,240,000; Scotland 1,080,000. In the South Wales district, the great Dowlais Works alone figure for 18 blast furnaces and a produce of 108,000 tons. The South Staffordshire district had numerous works, but none very large, the highest comprising five furnaces; the weekly yield varied from 80 to 150 tons per furnace. The Scotch works comprised many of large extent, such as the Gartsherrie with 16 furnaces, and the Dundyvan and Monkland with 9 each; the produce was very high, for none of the furnaces figured for less per week than 120 tons, and the average rose to 145. The most surprising advance, between 1839 and 1855, had been made in the Tees district, or Durham and North Yorkshire, owing to the discovery of ironstone in the Cleveland hills. This district had only 5 furnaces, of 50 tons weekly yield each, in 1839; whereas it had 79 furnaces, of 132 tons yield, in 1855. The largest or most powerful furnaces were in Monmouthshire (belonging to the so-called South Wales iron district), where some of them had a yield of more than 200 tons per week.

Mr. Truran was careful to state that the above were the producing *powers* of all our iron works, if all the furnaces had been in full blast throughout the whole year. But this is never the case; there are always many furnaces out of blast, and many periods of slackened operations. He selected the preceding year, 1854, to show actual instead of potential results; and he found them as follows:—

1854.	
Furnaces in blast	599
Weekly average per furnace	118 tons
Pig-iron manufactured	3,585,906 ,,

In the 16 years from 1839 to 1854, the furnaces in blast had increased from 379 to 599; the weekly average produce per furnace from 63 to 118 tons; and the total produce from (about) 1,250,000 tons to 3,590,000 tons—very nearly three-fold. To produce these 3,590,000 tons, Mr. Truran estimates that there were required

Clay ironstone	7,366,000 tons
Carboniferous ironstone	3,845,000 ,,
Siliceous ironstone	580,000 ,,
Hæmatite ironstone	555,000 ,,
Limestone as a flux	2,450,000 ,,
Coal as fuel	20,046,000 ,,
	34,842,000

Or, nearly 10 tons of crude material to make 1 ton of iron; but there seems to be included here, not only the coal for actual smelting, but also that for refining, casting, forging, &c. Almost as much coal is needed for converting pig-iron into malleable as for smelting from the ore. It is necessary to bear in mind that, for this same year 1854, Mr. Blackwell gave an estimate much below Mr. Truran's in the quantity of iron made, and still further below in the quantity of coal used; but the grounds for his estimate were not so fully stated. Mr. Blackwell allows 3 tons of coal for smelting 1 ton of iron, and 3 tons for converting 1 ton of pig iron into malleable.

Mention has more than once been made, in the foregoing paragraphs, of the vast Dowlais Works. No better example could be selected to illustrate the general character of all such establishments. More than a hundred years ago, the Earl of Windsor granted a lease of a portion of ground near (what was at that time) the small agricultural village of Merthyr Tydvil, on the confines of the counties of Glamorgan, Monmouth, and Brecknock; with a right to use the coal, iron, and limestone found beneath the surface. On this ground was erected a blast-furnace, which became the pattern or model for many others. On account partly of the smallness of the furnace, but still more of the imperfection of the smelting operations, the weekly yield of pig-iron per furnace was small. Forty years after the establishment of the works it was only 20 tons; by the year 1800 it had risen to 36; and taking successive intervals of ten years, it appears that the weekly yield per furnace was 50 tons in 1810, 62 in 1820, 78 in 1830, 88 in 1840, 102 in 1850; while the details already given show how probable it is that the yield will be vastly greater in 1860. Not only did the yield per furnace increase in this way, but the number of furnaces also underwent many augmentations. At the beginning of the present century there were 3, 4 in 1815, 8 in 1820, 12 in 1826, 18 at present; these being all *blast*-furnaces, irrespective of a much greater number of calcining, puddling, refining, founding, and other furnaces. Very early in the operations a Mr. Guest was one of the partners; and in the course of time his successors became sole owners of the vast property. The late Sir John Guest was a remarkable man: he learned practically all the operations of iron-making, from beginning to end; he made himself acquainted with the Welsh language, in order to become intimate with his work-people; and even when he possessed a residence of almost feudal magnificence at Morlais Castle, and had married a peer's daughter, his heart was still among the smoke and din of the works. Dowlais made 10,000 tons of pig-iron in 1810; whereas, in 1849, it made 100,000 tons. In 1852 it was calculated that the various furnaces and operations employed 5000 horse-power of steam-engines; that there were raised 2,000,000 tons of minerals from the ground beneath the estate, of which 800,000 tons consisted of ironstone, limestone, and coal, actually thrown into the furnaces; that *a ship a day* was freighted at Cardiff, on an average, with iron brought down from Dowlais by the Taff Vale railway and the Glamorganshire canal; that 10,000*l.* a week was paid in wages, the mere procuring of which by the appointed day, in coin, was a financial operation of no small magnitude; and that 7000 persons were employed at direct pay, who of course supported many thousands more at home. Some of the machinery is of the largest kind ever employed in iron-works. In 1857 there was a steam-engine powerful enough to blow the blast for six of the greatest furnaces; it had a beam of 40 tons, and a fly-wheel of 35 tons. The rolling-mill had a fly-wheel 21 feet in diameter, and a driving-wheel still larger. The rail-mill was capable of making 1000 tons of railway bars per week. Ever since the rise of the railway system, Dowlais has been famed for its railway bars more than for its castings; when it made 100,000 tons of iron per annum, three-fourths were sent from the works in the form of bars and rails. It is at night that the works should be seen, when all the furnaces are vomiting forth their flames high into the air, throwing around a lurid smoky light of extraordinary character. Most of the blast-furnaces are ranged in a semicircle, on the outside of which have gradually accumulated millions of tons of slag and rubbish; this slag, hot within long after it has become cool on the outside, occasionally cracks, and exhibits waving lines of red fire, bearing more resemblance to a volcano than anything else to be seen in this country. These vast heaps of rubbish are gradually filling up valleys, for there is no where else to place them; and portions of the upper section of the Taff Vale railway are laid on the slag itself, smoothed and graduated for the purpose. Within the works, noise, smoke, and heat are the three characteristics which overbear all others, and which leave an impression on the mind of a visitor not readily effaced.

IRON BOATS AND SHIPS. [SHIP-BUILDING.]

IRON BRIDGES. [BRIDGES.]

IRONY (εἰρωνεία), a refined species of ridicule, which under the guise of earnestness and simplicity exposes all undue pretensions, even while it professes to honour and admit them. It stands intermediate between naiveté, or frank simplicity, on the one hand, and banter and persiflage, on the other. From the former it is distinguished by the consciousness and intention of ridicule, which object again is more covert and less transparent in irony than in the latter. By Aristotle the ironical is opposed to the boastful (τῷ ἀλάζονι), and as a middle term between *the two* he places the truthful (τὸν ἀληθῆ). The Latins translated the word irony by "dissimulatio,' which however Quintilian (lib. ix., c. 2) disapproves of as very inadequate, and preferred the original, for which we are indebted to the refinement of the Athenians, among whom Socrates, the master in this art, was called emphatically the Ironical (ὁ εἴρων). The strict etymology of the term is very doubtful. One explanation, looking to the so-called Socratic method of question and answer, takes it to mean simply "the interrogator;" while another would derive it from εἴρειν, to fasten, which may have had reference to the skill wherewith Socrates reduced the sophists to the necessity of adopting some fixed and stable point for discussion, instead of loose and slippery declamation, which, as more favourable to delusion and fallacy, they preferred. Both explanations equally leave out of consideration that element of latent mockery which predominates in the modern acceptation of the word, but which was probably only accessory to the original idea. For while the serious object of the Socratic irony, in which he represented himself as desirous to learn of those whose claim to wisdom he laboured to expose, was to awaken reflection by the development of the consciousness, he nevertheless combined with it all the Attic urbanity and wit. It was consequently of two kinds, a finer and a grosser, according as he had to do with the more presumptuous arrogance of the sophists, whose undue and pernicious reputation he sought to subvert, or with those younger but not less conceited spirits, who yet sought his society for the sake of benefit and improvement, and therefore required a milder and more merciful treatment.

The ironical argument proceeds in simulated ignorance, and by appearing to agree with those whom its purpose is to refute, in holding certain erroneous opinions and maxims, brings out the antagonism of truth to error, and gradually involves them in inextricable difficulties. On this account it has been considered a species of apogogical argument (τῆς εἰς ἀδύνατον ἀπαγωγῆς), or reductio ad absurdum.

As a figure of rhetoric, it is correctly defined to be that mode in which our words convey a sense directly contrary to what we express, but agreeable to what we mean and are understood to mean. (Beattie, 'Moral Science,' c. i. § 1, p. 4.) In an opposite and somewhat extended sense those mistakes have been called ironical wherein our intended expressions receive an inverted signification.

Since the essence of irony consists in its serious and seeming simplicity, it is essential to its successful application that it should advance gradually to its ultimate object of exposure, and neither lose its covert character by rising too suddenly to exaggeration and extremes, nor yet so closely veil itself but that the intention of ridicule may appear through the assumed mask of earnestness and simplicity.

Of English writers Swift contains the strongest and the most numerous examples of irony.

IROQUOIS. [NORTH AMERICAN INDIANS.]

IRRADIATION denotes, properly, the emission of rays from a luminous object, but the word is generally used to signify an apparent enlargement of the disc of a celestial body: this enlargement being caused either by a deviation of the rays of light from a rectilinear direction, or by some illusion arising from the action of light on the eye.

When rays of light from points at the surface of an object fall on the retina, there may be produced on the latter an agitation extending within short distances about the points to which the rays in the pencils are made to converge by the humours of the eye: hence there may arise a perception of a fringe or border about a luminous body, and consequently an apparent enlargement of such body. Thus, the image of a star, when seen by the eye, appears to be a disc of sensible magnitude, instead of a mere point; which, on account of its remoteness, would be the case if the rays of each pencil produced no effect beyond their mathematical point of convergence: the disc of the sun or of the moon is conceived to be, in like manner, apparently enlarged; and thus, also, the part of the moon which, when the latter is new, is enlightened by the sun, appears to be a portion of a sphere of greater diameter than the part which is more faintly enlightened by the rays reflected from the earth.

A species of irradiation is caused by the blending together, upon the retina, of the circles of light produced by the pencils which fall upon it either before or after the rays in each have converged to a point; the humours of the eye not permitting that convergence to take place exactly on the membrane. A similar effect may be produced, to a greater or less degree, in a telescope, in consequence of defects in the object-glass, the irrationality of dispersion [DISPERSION], and diffraction, from all which the image of a luminous point is not a mere point, but has an apparent magnitude.

Before the invention of telescopes, the apparent magnitudes of celestial bodies were very erroneously estimated: thus, Tycho Brahé made the diameter of Venus twelve times and Kepler made it seven times as great as it is now known to be. Telescopes do not entirely remove the cause of such error, but, by increasing the diameters under which the bodies are seen, without at the same time magnifying the effect of irradiation, the error in the estimation of their apparent magnitudes is proportionally diminished.

It is a consequence of irradiation, that objects which are in reality of equal magnitudes appear frequently to differ in size according to their colour or to the quantity of light which falls upon them. Sir William Herschel remarked ('Phil. Trans.,' 1783) that when a bright circle was viewed together with a dark one on a bright ground, the latter always appeared smaller than the other; and, in order to correct the erroneous estimate of the magnitudes of the columns about temples when they are seen against a bright ground, it appears that the ancients made the thickness of the columns to increase proportionally to the distance between them. The reason assigned for this practice by Vitruvius ('De Architectura,' lib. 3, cap. 2) is, that the columns with wide intervals, being more surrounded by the air than those which are closer, appear on that account to be more slender. It must be observed, however, that the perceptions of magnitude depend partly on those of distance; and a contrary effect frequently takes place with objects viewed against the sky when conceived to be more remote than they really are.

IRRATIONAL QUANTITY. The distinction between quantity in general and number, or rather between the ratio of quantity to quantity, and that of number to number, has begun to appear in the article INCOMMENSURABLE, of which the present may be taken as a continuation. It there appears that there are such things as magnitudes which are not in the proportion of any one number to any other; though, if we may use numbers as great as we please, we can find a pair which shall be as nearly as we please in the ratio of any two given incommensurable quantities.

According to the modern use of the term irrational, it simply means not expressible by a finite fraction. The word *ratio*, or its equivalent *λόγος*, does not here mean reason, in the common sense of the word, but mathematical proportion. A quantity whose ratio to the unit of quantity cannot be expressed arithmetically, that is, by a whole number or a fraction, is "inexpressible by an arithmetical ratio," or "arithmetically irrational," abbreviated into "irrational." This explanation is very important, since the student might otherwise be led to suppose that irrational meant unreasonable, or absurd. Looking at the manner in which the common meaning of the word irrational is fixed in our minds, it would be well if the mathematical word were connected with its cognate *ratio*, by being pronounced irrational. Suppose for example that we have a geometrical problem which we solve by the application of arithmetic, taking a certain line to be unity, and applying the fundamental principles explained in RECTANGLE. Suppose the problem thus reducible to the solution of $x^2=2$, or the quantity sought is such a fraction as multiplied by itself will give 2. The arithmetical answer is very simple; there is no such fraction. But is the problem therefore impossible? By no means; for the line required must be the diagonal of a square whose side is the linear unit. What then is the reason for our not being able to produce an arithmetical solution? Because the ratio of the line sought to the linear unit given is not to be expressed arithmetically, or is in the preceding sense irrational. The student has now arrived at the point where he must be taught (if he have not learnt it before) that common arithmetic is not the science of all ratios or relative magnitudes, but only of the ratios or relative magnitudes of those quantities which are made by putting together quantities which are all equal to one another. The senses alone would never make this distinction, and those who desire nothing more than sensible evidence in their mathematical studies need not attend to it: unfortunately the present bent of such pursuits tends to inexactness, not explicitly avowed, but wearing the appearance of absolute rigour.

The student who begins to extract the square root of numbers is allowed to place the symbol of that process over numbers which do not admit of its performance, as $\sqrt{2}$, $\sqrt{3}$, &c. These symbols are reasoned on as if they represented fractions, and arithmetical deductions are drawn; but when it is required to reduce them to practice, then the possibility of determining their arithmetical values is denied, and it is implied that they have an existence which can only be approximately represented. Thus, since 1·4142 multiplied by itself gives 2 very nearly, it is said that 1·4142 is very nearly the square root of 2. This method, which is indispensably necessary in practice, should not be allowed in perfectly strict reasoning. It cannot be just to say that 2 has no square root, but that since fractions very near to 2 have square roots, therefore these square roots are very near to the non-existent square root of 2. It is only in a properly extended arithmetic, which by express agreement admits of extended symbols of ratio, that it can be lawful to speak of the square root of 2. [RATIO.] Waiving this point for the present, we proceed to further considerations, confining ourselves to those irrational quantities which arise from taking the square roots of numbers, but premising that similar remarks might be made on cube, fourth, &c., roots. If we take the series of numbers 1, 2, 3, &c., and extract the square root of each, we thereby obtain (1.) the original series 1, 2, 3, &c., by means of $\sqrt{1}$, $\sqrt{4}$, $\sqrt{9}$, &c.; (2.) a series of multiples of $\sqrt{2}$, namely, $\sqrt{2}$, $\sqrt{8}$, $\sqrt{18}$, &c., which are $\sqrt{2}$, $2\sqrt{2}$, $3\sqrt{2}$, &c.; (3.) a similar series of multiples of $\sqrt{3}$; and so on ad infinitum. The primitive numbers are either prime numbers or products of *different* prime numbers. Thus we have a series of multiples of $\sqrt{(7\times 5)}$, but not of $\sqrt{(7\times 7\times 5)}$, since this last is $7\sqrt{5}$, and, with its multiples, is included in those of $\sqrt{5}$. Any two quantities in the same series are commensurables; thus $7\sqrt{10}$ and $12\sqrt{10}$ are in the proportion of 7 to 10, and have $\sqrt{10}$ for a common measure: but any two which are in different series are incommensurables; thus $\sqrt{10}$ and $\sqrt{11}$ have no common measure whatsoever. And the sum or difference of any two incommensurable quantities is incommensurable with either; thus we can form infinite sets of binomials, such as $\sqrt{2}+\sqrt{3}$, $\sqrt{10}+\sqrt{11}$, $\sqrt{19}-\sqrt{5}$, &c., no one of which shall be commensurable with any other.

The square root of any arithmetical fraction is commensurable with that of the product of its numerator and denominator: thus $\sqrt{(\frac{3}{5})}$ is $\frac{1}{5}\sqrt{15}$. And the reciprocal of any square root is commensurable with that square root: thus $1\div\sqrt{7}$ is $\frac{1}{7}\sqrt{7}$. Also the fraction made by any two of the binomials just described is commensurable with the product of some similar pair: thus

$$\frac{\sqrt{3}+\sqrt{5}}{\sqrt{10}-2}=\tfrac{1}{6}(\sqrt{3}+\sqrt{5})(\sqrt{10}+2).$$

If we take the square root of one of the preceding binomials, a $\sqrt{(\sqrt{3}+\sqrt{5})}$ we have a new quantity, not commensurable with any of those just mentioned, except only in certain cases pointed out by the following theorem. Let a and b be two numbers, of which a is the greater:—

$$\sqrt{(\sqrt{a}\pm\sqrt{b})}=$$
$$\sqrt{\left(\frac{\sqrt{a}+\sqrt{(a-b)}}{2}\right)}\mp\sqrt{\left(\frac{\sqrt{a}-\sqrt{(a-b)}}{2}\right)}$$

If a and $a-b$ be both square numbers, let $a=p^2$, $a-b=q^2$, and we have

$$\sqrt{(\sqrt{a}\pm b)}=\tfrac{1}{2}\sqrt{(2p+2q)}\pm\tfrac{1}{2}\sqrt{(2p-2q)}.$$

Though Euclid was not acquainted with any direct algebraical process, yet he carried the distinction of incommensurable quantities to the length of a complete subdivision of all the possible cases which can be contained in the formula $\sqrt{(\sqrt{a}\pm\sqrt{b})}$. We are induced to give an account of his tenth book, because there does not, to our knowledge, exist any such thing in a form accessible to the student. Indeed, we do not know where to find a description of its details in any form whatsoever. In old geometrical writings references to the classification of this book are not unfrequently met with. If we take any given line to represent the unit of length, and if a, b, c, &c., represent lines commensurable with this unit, arithmetically expressed, it is well known that the most common geometry shows how to find the lines expressed by $\sqrt{a}$, $\sqrt{b}$, &c. All such lines Euclid terms rational, all others irrational (*ῥητος* and *ἄλογος*); and any area which being formed into a square has a rational side, he calls a rational area; that is, in fact, any area which is commensurable (*σύμμετρος*) with the square unit is rational. The term for the square on a line is its *power* (*δύναμις*), and from this comes the algebraical use of the word power. Thus, when he says that two lines are only commensurable in power, he means that the squares on them are commensurable, but not the lines themselves. A mean, or medial line (*μέσος*), is the mean proportional between two incommensurable rational lines, and is such as can be represented in algebra by $\sqrt[4]{a}$, where a is commensurable with the unit; and a medial area is the mean proportional between two rational areas, and its number of square units may be represented by $\sqrt{a}$.

A line which is made by putting together (*σύνθεσις*) two incommensurable rational lines is called a line of two names (*ἐκ δύο ὀνομάτων*), or a binomial line; while one which is made by taking away (*ἀφαίρεσις*) the lesser of two incommensurable rational lines from the greater is called an apotomé (*ἀποτομή*), literally, off-cut. The binomial therefore has one of the forms $a+\sqrt{b}$, and $\sqrt{a}+\sqrt{b}$, while the apotomé has one of the forms $\sqrt{a}-\sqrt{b}$, $a-\sqrt{b}$, $\sqrt{b}-a$. Six distinct species of each sort of line are found, and in connection with each set of six is another similar set, which a modern mathematician would describe as composed of the square roots of the first set. But Euclid describes the square roots as we should call them, previously to the lines themselves; and in order to render this article more available to those who look through the tenth book, we shall do the same. The whole amounts to this: that, taking a given line as the unit and standard, Euclid separates the lines represented by $\sqrt{(\sqrt{a}\pm\sqrt{b})}$, where a and b are commensurable with the standard unit, into twenty-five distinct classes, no one of which contains any lines commensurable with those of any other class. The following enumeration contains the order in which they make their appearance: a, b, &c., representing lines commensurable with the standard unit; A, B, C, D, E, F, the six binomial lines: $\sqrt{A}$, $\sqrt{B}$, &c., those connected with them: U, V, W, X, Y, Z, the six apotomæ: $\sqrt{U}$, $\sqrt{V}$, &c., those connected with them.

It is, however, to be noticed, that Euclid does not use the term unit, but supposes a rational line, to which he makes reference. Thus when he mentions in one place a rational line and a fourth binomial, he means that the fourth binomial shall be related to that rational line in the same manner as our following definition will connect it with the modern phrase, the standard unit.

(1). a, b, &c., lines commensurable with the unit.

(2). $\sqrt{a}$, $\sqrt{b}$, &c., lines commensurable in power with the unit. These two heads include the rational lines.

(3). $\sqrt[4]{a}$, $\sqrt[4]{b}$, &c., medial lines, described by Euclid as lines equal in power to the rectangle of incommensurable rational lines.

( ). $\sqrt{A}$ has the form $\sqrt{a}+\sqrt{b}$. A binomial line generally. This case contains all the six hereafter described and numbered, for which reason the numbering is here left blank. There is a proposition which we should now enunciate by saying that the square root of a binomial of the first species (A) is one or other, and may be either, of the six binomials.

(4). $\sqrt{B}$ has the form $(\sqrt{a}+\sqrt{b})\sqrt[4]{x}$, where abx is a square number. It is the first species of line composed of two medials, or a first bi-medial, and is compounded of two medials, which make a rational rectangle (*εὐθεῖα ἐκ δύο μέσων πρώτη*).

(5). $\sqrt{C}$ has the form $(\sqrt{a}+\sqrt{b})\sqrt[4]{x}$, where abx is not a square number. It is the second species of line composed of two medials, or a second bi-medial, and is compounded of two medial lines, which make a medial rectangle (*εὐθεῖα ἐκ δύο μέσων δευτέρα*).

(6). $\sqrt{D}$ has the form $\sqrt{(a+\sqrt{b})}+\sqrt{(a-\sqrt{b})}$, where a^2-b is not a square. It is described by Euclid as composed of two straight lines, incommensurable in power, whose squares together make a rational space, but whose rectangle is a medial space, and is called by him a greater line (*εὐθεῖα μείζων*).

(7). $\sqrt{E}$ has the form $\sqrt{(\sqrt{a}+\sqrt{b})}+\sqrt{(\sqrt{a}-\sqrt{b})}$, where $a-b$ is a square. It is described by Euclid as composed of two straight lines incommensurable in power, whose squares together make a medial space, but whose rectangle is a rational space; and it is called by him "a line in power making a rational and a medial space" (*εὐθεῖα ῥητὸν καὶ μέσον δυναμένη*). The nomenclature is not here quite correct, for the preceding line, called a greater line, is also a line in power equal to a rational and medial space.

(8). $\sqrt{F}$ has the form $\sqrt{(\sqrt{a}+\sqrt{b})}+\sqrt{(\sqrt{a}-\sqrt{b})}$, where $a-b$ is not square. It is described by Euclid as composed of two lines incommensurable in power, making both the sum of their squares and their rectangle medial spaces incommensurable with one another; and it is called "a line in power equal to two medial spaces" (*εὐθεῖα δύο μέσα δυναμένη*).

We now come to the description of the six binomial lines themselves.

(9). A has the form $a+b+2\sqrt{(ab)}$. It is described by Euclid as having the greater term commensurable with the standard unit, and more in power than the less by the square of a line commensurable with itself in length; and it is called the first binomial line (*εὐθεῖα ἐκ δύο ὀνομάτων πρώτη*).

(10). B has the form $(a+b+2\sqrt{(ab)})\sqrt{x}$, √where abx is a square. It is described as differing from the first binomial only in having the lesser term commensurable with the standard unit; and is the second binomial line.

(11). C has the form $(a+b+2\sqrt{(ab)})\sqrt{x}$, where abx is not a square. It differs from the two preceding only in neither term being commensurable with the standard unit.

In the first three binomial lines, reduced to the form $\sqrt{p}+\sqrt{q}$, $\sqrt{(p-q)}$ is commensurable with $\sqrt{p}$, the greater term: in the last three these two are incommensurable.

(12). D has the form $a+\sqrt{b}$, where a is greater than $\sqrt{b}$, and a^2-b is not a square. Euclid describes it as having the greater term more in power than the less by the square of a line incommensurable to itself in length, the same greater term being commensurable with the standard unit: it is the fourth binomial line.

(13). E has the form $a+\sqrt{b}$, where $\sqrt{b}$ is greater than a, and $b-a^2$ is not a square. It is described as differing from the preceding by having the less term commensurable with the standard unit: it is the fifth binomial line.

(14). F has the form $\sqrt{a}+\sqrt{b}$, where $a-b$ is not a square. It is described as differing from the two preceding by neither term being commensurable with the standard unit; and is the sixth binomial line.

We now come to the lines derived from the apotomæ, and afterwards to the apotomæ themselves. The descriptions might be shortened by allusion to the corresponding binomial lines, but this would impede the speedy reference to the complete meaning of any one term.

( ). $\sqrt{U}$ has the form $\sqrt{a}-\sqrt{b}$. An apotomé generally. The numbering is left blank, as this class of lines is afterwards subdivided. A proposition is proved, which we should now enunciate by saying hat the square root of an apotomé of the first kind is one or other, and may be any of the six apotomæ.

(15). $\sqrt{V}$ has the form $(\sqrt{a}-\sqrt{b})\sqrt[4]{x}$ where abx is a square. Euclid describes it as the difference of two medial lines which are commensurable in power, and whose rectangle is a rational space. He calls it the first kind of apotomé of a medial line (*μέσης ἀποτομὴ πρώτη*).

(16). $\sqrt{W}$ has the form $(\sqrt{a}-\sqrt{b})\sqrt[4]{x}$, where abx is not a square. It is described as differing from the former only in the medial lines containing a medial space, and is the second apotomé of a medial line.

(17). $\sqrt{X}$ has the form $\sqrt{(a+\sqrt{b})}-\sqrt{(a-\sqrt{b})}$ where a^2-b is not a square. Euclid describes it as the difference of two straight lines incommensurable in power, the sum of whose squares is rational, and their rectangle medial: and he calls it a lesser line (*εὐθεῖα ἐλάσσων*).

(18). $\sqrt{Y}$ has the form $\sqrt{(\sqrt{a}+\sqrt{b})}-\sqrt{(\sqrt{a}-\sqrt{b})}$ where $a-b$ is a square. It is described as the preceding, except that the sum of the squares is medial, and the rectangle rational: and Euclid calls it "a line which with a rational space makes a medial space" (*εὐθεῖα μετὰ ῥητοῦ μέσον τὸ ὅλον ποιοῦσα*) meaning that a certain rational space added to the square on it makes a whole space which is medial. There is not here the defect of nomenclature mentioned in (7), for the preceding line here can only be called "a line which with a medial space makes a rational space."

(19). $\sqrt{Z}$ has the form $\sqrt{(\sqrt{a}+\sqrt{b})}-\sqrt{(\sqrt{a}-\sqrt{b})}$ where $a-b$ is not a square. It is described by Euclid as the difference of two lines incommensurable in power, having the sum of their squares and their rectangle both medial: and it is called "a line which with a medial space makes a medial space" (*εὐθεῖα μετὰ μέσου μέσον τὸ ὅλον ποιοῦσα*).

The six apotomæ now follow, all in the form $\sqrt{a}-\sqrt{b}$; in the first three $\sqrt{(a-b)}$ is commensurable with $\sqrt{a}$, in the second three, incommensurable. And $\sqrt{a}$ is called the whole, but $\sqrt{b}$ is called the fitted or adapted line.

(20). U has the form $a+b-2\sqrt{(ab)}$. The whole is commensurable with the standard unit, and exceeds the adapted line in power by the square of a line commensurable with itself. Euclid calls this a first apotomé.

(21). V has the form $(a+b-2\sqrt{(ab)})\sqrt{x}$ where abx is a square. Described as the preceding, except that only the adapted line is commensurable with the standard unit; and is the second apotomé.

(22). W has the form $(a+b-2\sqrt{(ab)})\sqrt{x}$, where abx is not a square. Here neither the whole nor the adapted line is commensurable with the standard unit; this is the third apotomé.

(23). X has the form $a-\sqrt{b}$ where a^2-b is not a square. Euclid describes it by saying that the whole is commensurable with the standard unit, and exceeds the adapted line in power by the square of a line incommensurable with itself; and calls it the fourth apotomé.

(24). Y has the form $\sqrt{b}-a$ where $b-a^2$ is not a square. Described as the last, excepting that only the adapted line is commensurable with the standard unit: it is the fifth apotomé.

(25). Z has the form $\sqrt{b}-\sqrt{a}$ where $b-a$ is not a square. It differs from the two preceding by neither term being commensurable with the standard unit: and is the sixth apotomé.

Besides obtaining this classification, Euclid proves, firstly, that every one of these species is distinct from every other, and that every line which is commensurable with a line of any one species is itself a line of the same species. He shows also how to find lines of every species in which he directly applies the theory of numbers obtained in the seventh, eighth, and ninth books. He also demonstrates that no straight line can belong to one species in two different ways: proving, for example, an equivalent to the following, that $\sqrt{a}+\sqrt{b}$, if the terms be incommensurable, cannot be equal to $\sqrt{x}+\sqrt{y}$, where x differs from a, and y from b: which he expresses thus:—"a binomial line is divided into its names (or terms) in one point only." He then proves that the lines which we have denoted by $\sqrt{A}$, $\sqrt{B}$, &c., are derived from A, B, &c., in the manner which justifies our notation. For instance, "if a space be contained by a rational and a fourth binomial line, the line equal in power to the space is the irrational line called a greater line." Now, c representing a rational line, a fourth binomial derived from it has the form $a+\sqrt{b}$ where a is commensurable with c, and greater than $\sqrt{b}$, and $\sqrt{(a^2-b)}$ is not commensurable with c. His proposition then amounts to this, that $\sqrt{(ca+c\sqrt{b})}$ has the form

$$\sqrt{(x+\sqrt{y})}+\sqrt{(x-\sqrt{y})}$$

where $2x$ is a rational space (or the number $2x$ commensurable with c^2), and x^2-y is an irrational space, or that number is incommensurable with c^2. This involves the algebraical proposition, that the square root of $ca+c\sqrt{b}$ is

$$\sqrt{\left\{\tfrac{1}{2}ca+\tfrac{1}{2}c\sqrt{(a^2-b)}\right\}}+\sqrt{\left\{\tfrac{1}{2}ca-\tfrac{1}{2}c\sqrt{(a^2-b)}\right\}};$$

and in showing the identity of the forms, Euclid arrives at the manner of deriving one from the other. He also shows, in two propositions, that the form $\sqrt{(a+\sqrt{b})}$ gives either a binomial line, or (4), (6), or (7) of the preceding enumeration, and that $\sqrt{(\sqrt{a}+\sqrt{b})}$ gives either (5) or (8). In three more he shows that $\sqrt{(a-\sqrt{b})}$ gives either an apotomé or (17) of the enumeration, that $\sqrt{(\sqrt{b}-a)}$ gives either (15) or (18), and that $\sqrt{(\sqrt{a}-\sqrt{b})}$ gives either (16) or (19). He further shows the equivalent of the following algebraical proposition:—

$$\frac{1}{\sqrt{a}-\sqrt{b}}=\frac{\sqrt{a}+\sqrt{b}}{a-b}$$

The preceding enumeration points to one of the most remarkable pages in the history of geometry. The question immediately arises, had Euclid any substitute for algebra? If not, how did he contrive to pick out, from among an infinite number of orders of incommensurable lines, the whole, and no more than the whole, of those which were necessary to a complete discussion of all lines represented by $\sqrt{(\sqrt{a} \pm \sqrt{b})}$, without one omission or one redundancy? He had the power of selection, for he himself has shown how to construct an infinite number of other species, and an algebraist could easily point out many more ways of adding to the subject, which could not have been beyond Euclid. If it be said that a particular class of geometrical questions, involving the preceding formula and that one only, pointed out the various cases, it may be answered that no such completeness appears in the thirteenth book, in which Euclid applies his theory of incommensurables. It is there proved that each of the segments of a line divided in extreme and mean ratio is an apotomé—that the side of an equilateral pentagon inscribed in a circle is, relatively to the radius, the irrational line called a lesser line, as is also the side of an icosahedron inscribed in a sphere—and that the side of a dodecahedron is an apotomé. The apotomé then and the lesser line are the only ones applied.

It seems probable that the distinction of commensurable and incommensurable, and even a notion of different species of incommensurables, was familiar to the geometer before Euclid wrote: and this may be inferred, almost with certainty, from what is said by Proclus. Had it been otherwise, we must suppose that the definitions of the fifth book would have been accompanied by some little account of their necessity, and also that the absolute determination of two incommensurable magnitudes would not have been postponed till the last proposition of the tenth book. But it is impossible to draw any very positive conclusion on this subject. Owing to the loss of Euclid's book on Fallacies [Geometry], we are probably left without those notions which he intended to be preliminary to the elements.

The most conspicuous propositions of elementary geometry which are applied in the tenth book are the 27th, 28th, and 29th of the sixth book, of which it may be useful to give the algebraical signification. The first of these (the 27th) amounts to showing that $2x-x^2$ has its greatest value when $x=1$, and contains a limitation necessary to the conditions of the two which follow. The 28th proposition is a solution of the equation $ax-x^2=b$, upon a condition derived from the preceding proposition, namely, that $\frac{1}{4}a^2$ shall exceed b. It might appear more correct to say that the solution of this equation is one particular case of the proposition, namely, where the given parallelogram is a square; but nevertheless the assertion applies equally to all cases. Euclid however did not detect the *two* solutions of the question; though if the diagonal of a parallelogram in his construction be produced to meet the production of a line which it does not cut, the second solution may be readily obtained. This is a strong presumption against his having anything like algebra; since it is almost impossible to imagine that the propositions of the tenth book, deduced from any algebra, however imperfect, could have been put together without the discovery of the second root. The remaining proposition (the 29th) is equivalent to a solution of $ax+x^2=b$: but the case of $x^2-ax=b$ is wanting, which is another argument against Euclid having known any algebraical reasoning.

IRREDUCIBLE CASE (that is, of cubic equations), the common name of a particular class of cubic equations, to which Cardan did not succeed in applying his celebrated rule. Bombelli however showed that the reason of this was the reality of all the three roots. The following is the sketch both of the method and the difficulty. [Bombelli; Cardan; Tartaglia, in Biog. Div. Theory of Equations; Negative and Impossible Quantities.]

Unity has three cube roots, 1, $-\frac{1}{2}(1-\sqrt{-3})$, and $-\frac{1}{2}(1+\sqrt{-3})$, of which the product of the second and third is possible and equal to unity. Calling these 1, r, and r', it is next shown that a^3 has three cube roots, namely, a, ra, and $r'a$. Now, let there be a cubic equation (A, B, and C being real quantities)

$$x^3+\mathrm{A}x^2+\mathrm{B}x+\mathrm{C}=0;$$

and, by the method explained in Involution and Evolution, find another equation which has each root greater than a root of the preceding by $\frac{1}{3}\mathrm{A}$. We have then

$$x^3+\mathrm{P}x+\mathrm{Q}=0 \quad . \; . \; . \quad (1)$$

$$\mathrm{P}=\mathrm{B}-\tfrac{1}{3}\mathrm{A}^2 \qquad\qquad \mathrm{Q}=\mathrm{C}-\tfrac{1}{3}\mathrm{AB}+\tfrac{2}{27}\mathrm{A}^3.$$

Let x be $v+w$: then $x^3=v^3+w^3+3vwx$, and (1) becomes

$$v^3+w^3+(3vw+\mathrm{P})\,x+\mathrm{Q}=0 \quad . \; . \quad (2).$$

Determine v and w so that

$$3vw+\mathrm{P}=0 \qquad\qquad v^3+w^3+\mathrm{Q}=0;$$

by which means (2), and therefore (1), is satisfied. This gives

$$v^3\ (\text{or } w^3)=-\tfrac{1}{2}\mathrm{Q}+\sqrt{(\tfrac{1}{4}\mathrm{Q}^2+\tfrac{1}{27}\mathrm{P}^3)}$$
$$w^3\ (\text{or } v^3)=-\tfrac{1}{2}\mathrm{Q}-\sqrt{(\tfrac{1}{4}\mathrm{Q}^2+\tfrac{1}{27}\mathrm{P}^3)},$$

from which v and w can be found. But as each of the two, v^3 and w^3, has three cube roots; and as no reason yet appears for choosing one rather than another, it should seem as if the possible combinations by which $v+w$ might be made would be nine in number. But on looking back we find the condition $3vw=-\mathrm{P}$; so that the product of v and w must be a possible quantity. And since nothing but P^3 appears in v and w, the same values of v and w would appear whatever cube root of P^3 might have appeared in the original equation: consequently the six values of $v+w$ which are now to be abandoned belong to the roots of $x^3+\mathrm{P}r\,x+\mathrm{Q}=0$, and $x^3+\mathrm{P}r'\,x+\mathrm{Q}=0$. If then we signify by v and w the real cube roots of v^3 and w^3, the others are rv and $r'v$, rw and $r'w$; and the only combinations which satisfy the condition $3vw+\mathrm{P}=0$ are

$$v+w,\ rv+r'w,\ r'v+rw,$$

which are the three roots of the equation (1): to the exclusion of $v+rw$, $rv+w$, $r'v+r'w$, the roots of $x^3+\mathrm{P}r\,x+\mathrm{Q}=0$; and $v+r'w$, $r'v+w$, $rv+rw$, the roots of $x^3+\mathrm{P}r'x+\mathrm{Q}=0$. So far all is right, and the algebraical solution is complete, and may be represented thus: let ρ stand for any cube root of unity; then the three solutions of (1) are contained in

$$\rho\sqrt[3]{\left\{-\tfrac{1}{2}\mathrm{Q}+\sqrt{(\tfrac{1}{4}\mathrm{Q}^2+\tfrac{1}{27}\mathrm{P}^3)}\right\}}$$
$$+\frac{1}{\rho}\sqrt[3]{\left\{-\tfrac{1}{2}\mathrm{Q}-\sqrt{(\tfrac{1}{4}\mathrm{Q}^2+\tfrac{1}{27}\mathrm{P}^3)}\right\}}$$

where $\sqrt[3]{\ }$ signifies the real cube root.

This is perfectly intelligible when $\frac{1}{4}\mathrm{Q}^2+\frac{1}{27}\mathrm{P}^3$ is a positive quantity: for if we call the real cube roots above mentioned K and L, we find for the three roots of the equation, first, the possible root, K + L; next, the pair of impossible roots contained in the formula

$$-\tfrac{1}{2}(\mathrm{K}+\mathrm{L}\pm\tfrac{1}{2}(\mathrm{K}-\mathrm{L})\sqrt{-3}.$$

If we apply this to the equation $x^3-9x-28=0$, where $\mathrm{P}=-9$, and $\mathrm{Q}=-28$, we shall find $\mathrm{K}=3$, $\mathrm{L}=1$, and the roots are $4, -2+\sqrt{-3}$, and $-2-\sqrt{-3}$. But if it should happen that $\frac{1}{4}\mathrm{Q}^2+\frac{1}{27}\mathrm{P}^3$ is negative (which requires that P should be negative and $\frac{1}{27}\mathrm{P}^3$ numerically greater than $\frac{1}{4}\mathrm{Q}^2$), we return to the original form of the solution, and find that the roots of the equation are contained in the formula

$$\left\{\mathrm{V}+\mathrm{W}\sqrt{-1}\right\}^{\frac{1}{3}}+\left\{\mathrm{V}-\mathrm{W}\sqrt{-1}\right\}^{\frac{1}{3}} \quad . \; . \; . \quad (3)$$

where $\left\{\quad\right\}^{\frac{1}{3}}$ means any cube root, there being a tacit condition that the product of the two cube roots must be possible. (V stands for $-\frac{1}{2}\mathrm{Q}$, and W for the possible (though perhaps irrational) quantity $\sqrt{(-\frac{1}{4}\mathrm{Q}^2-\frac{1}{27}\mathrm{P}^3)}$. Now it is shown in books of algebra that every cube root of $\mathrm{V}+\mathrm{W}\sqrt{-1}$ is of the same form, say $\mathrm{F}+\mathrm{G}\sqrt{-1}$, and that the corresponding cube root of $\mathrm{V}-\mathrm{W}\sqrt{-1}$ is $\mathrm{F}-\mathrm{G}\sqrt{-1}$. If, then, we assume

$$\left\{\mathrm{V}+\mathrm{W}\sqrt{-1}\right\}^{\frac{1}{3}}=\mathrm{F}+\mathrm{G}\sqrt{-1},$$
$$\left\{\mathrm{V}-\mathrm{W}\sqrt{-1}\right\}^{\frac{1}{3}}=\mathrm{F}-\mathrm{G}\sqrt{-1},$$

we find by multiplication

$$\left\{\mathrm{V}^2+\mathrm{W}^2\right\}^{\frac{1}{3}}=\mathrm{F}^2+\mathrm{G}^2;$$

and by addition of their cubes, and division by 2,

$$\mathrm{V}=\mathrm{F}^3-3\mathrm{FG}^2,$$

between which the elimination of G gives

$$\mathrm{F}^3-\tfrac{3}{4}\sqrt[3]{\mathrm{V}^2+\mathrm{W}^2}\,.\,\mathrm{F}-\tfrac{1}{4}\mathrm{V}=0;$$

from which it would seem that we might find F, and then G. But on examining this last equation we find it to be precisely that kind of cubic equation about which the difficulty arose; for the P of this equation is negative, being $-\frac{3}{4}\sqrt[3]{(\mathrm{V}^2+\mathrm{W}^2)}$, and the Q is $-\frac{1}{4}\mathrm{V}$; and $\frac{1}{27}\mathrm{P}^3$, being $-\frac{1}{64}(\mathrm{V}^2+\mathrm{W}^2)$, is numerically greater than $\frac{1}{4}\mathrm{Q}^2$, or $\frac{1}{64}\mathrm{V}^2$. Whence this case is called irreducible; for though, as will be shown immediately, there are three possible values of the expression (3), yet every direct algebraical attempt to find them leads to the same difficulty in another form.

If F and G could be determined, one value of (3) is 2 F; and taking the other cube roots, selecting only those pairs whose products are possible, we find

$$-\tfrac{1}{2}(1+\sqrt{-3})\,(\mathrm{F}+\mathrm{G}\sqrt{-1})-\tfrac{1}{2}(1-\sqrt{-3})\,(\mathrm{F}-\mathrm{G}\sqrt{-1})$$
$$-\tfrac{1}{2}(1-\sqrt{-3})\,(\mathrm{F}+\mathrm{G}\sqrt{-1})-\tfrac{1}{2}(1+\sqrt{-3})\,(\mathrm{F}-\mathrm{G}\sqrt{-1})$$

for the other admissible values. These may be reduced to

$$-\mathrm{F}+\mathrm{G}\sqrt{3}, \text{ and } -\mathrm{F}-\mathrm{G}\sqrt{3},$$

which are both possible. Consequently, the irreducible case of a cubic equation is that in which the three roots are all possible.

Let us apply the preceding to $x^3-21x+20=0$. Here $\mathrm{P}=-21$, $\mathrm{Q}=20$, $\frac{1}{4}\mathrm{Q}^2+\frac{1}{27}\mathrm{P}^3=-243=-81\times3$. Hence the roots are contained in

$$\left\{-10+9\sqrt{3}\sqrt{-1}\right\}^{\frac{1}{3}}+\left\{-10-9\sqrt{3}\sqrt{-1}\right\}^{\frac{1}{3}}.$$

By trial (or by semi-tentative methods, described in many older books of algebra) it may be found that a cube root of $-10+9\sqrt{3}\ \sqrt{-1}$ is $2+\sqrt{3}\ \sqrt{-1}$; whence $\text{F}=2$, $\text{G}=\sqrt{3}$. Hence one root (2F) is 4; the second and third ($-\text{F}+\text{G}\sqrt{3}$ and $-\text{F}-\text{G}\sqrt{3}$), are $-2+3$ and $-2-3$, or 1 and -5.

But the best method of obtaining the roots is by having recourse to a registry of the roots of cubic equations which is in the hands of every tyro, namely, the tables of sines and cosines, by which also the theorem of Bombelli will be established, namely, that the difficulty of the irreducible case answers to that of the trisection of an angle in geometry. It is proposed then, by means of trigonometry, to calculate the values of (3). Assume $\text{V}=r\cos.\theta$, $\text{W}=r\sin.\theta$, or find r and θ from

$$r=\sqrt{\text{V}^2+\text{W}^2},\qquad \tan.\theta=\frac{\text{W}}{\text{V}}$$

in which that sign must be given to r, which gives $r\cos.\theta$ the sign of V. Then, by De Moivre's theorem [NEGATIVE AND IMPOSSIBLE QUANTITIES],

$$(\cos.\theta\pm\sin.\theta\sqrt{-1})^{\frac{1}{3}}=\cos.\tfrac{1}{3}\theta\pm\sin.\tfrac{1}{3}\theta\sqrt{-1},$$

in which, by substituting $\theta+360°$ or $\theta+720°$ for θ, the equation $\tan.\theta=\text{V}\div\text{W}$ is still satisfied, and while the first side of the preceding equation is not altered in appearance, the different values of the cube root appear on the second side. From this we readily find that the expression (3) is no other than $2\sqrt[3]{r}\,.\cos.\frac{1}{3}\theta$; the three values of which, obtained as just noted, are

$$2\sqrt[3]{r}\,.\cos.\tfrac{1}{3}\theta,\ 2\sqrt[3]{r}\,.\cos.(120°+\tfrac{1}{3}\theta),\ 2\sqrt[3]{r}\,.\cos.240°+\tfrac{1}{3}\theta)$$

which may be thus written:—

$$2\sqrt[3]{r}\,.\cos.\tfrac{1}{3}\theta,-2\sqrt[3]{r}\,.\cos.(60°-\tfrac{1}{3}\theta),-2\sqrt[3]{r}\,.\cos.(60°+\tfrac{1}{3}\theta.)$$

Thus, in the preceding example, which gives $\text{V}=-10$, $\text{W}=9\sqrt{3}$, we find $r^2=100+243=343=7^3$; whence $\sqrt[3]{r}=-\sqrt{7}$. And $\tan.\theta=-\frac{9}{10}\sqrt{3}$, whence θ is found to be $-(57°\ 19'\ 16'')$, one-third of which is $-(19°\ 6'\ 25'')$, and this, with $79°\ 6'\ 25''$ and $40°\ 53'\ 35''$, are the angles on which the required values depend. The cosines of these angles, severally multiplied by $-2\sqrt{7}$, $2\sqrt{7}$, and $2\sqrt{7}$, give results as near to -5, 1, and 4 (the values found), as the unavoidable errors in the last places of logarithmic results, and the preceding rejection of fractions of seconds, will permit.

IRRIGATION. Of all the substances which concur in the vegetation and growth of plants water is the most essential; without moisture the seed cannot germinate, nor can the plant receive nourishment. Hence in warm climates, where rains are periodical, and where the soil is dried and parched by a continued evaporation, no verdure exists, except where springs or rivers supply the waste of moisture. The warmer the climate, and the more rapid the evaporation, the more luxuriant is the vegetation, provided there be an abundant supply of water. This circumstance has suggested the plan of diverting streams and conducting them in channels to fertilise as great an extent of land as possible. In China and in India, as well as in Egypt, ingenious modes of watering lands have been adopted from the most remote ages. No expense has been thought too great to secure a supply of water, and to distribute it in the most advantageous manner. It seems that where there is great heat in the air, water alone will supply the necessary food for the growth of plants. It is probable that the component parts of the atmosphere are more easily separated, and made to enter into new combinations with those of water, in a high temperature than in a lower; or that the leaves and green parts of vegetables imbibe water in a state of solution in air, and in this state it is more easily decomposed. Atmospheric air and water contain all the principal elements of vegetables, namely, oxygen, hydrogen, carbon, and nitrogen; the remainder are either found in the soil or diffused through the water.

Water has also an important office to perform, if we admit the principle discovered by Macaire, that plants reject through their roots those portions of the sap which are the residue of its elaboration, and which are of no further use to the plant, but rather injurious if they are again imbibed by the roots. Plants may perhaps require a removal of their excrements, as animals do when tied up in stalls, or confined in a small space; and the percolation of water through the soil may be the means which nature has provided for this purpose. Hence we can readily suppose that the mere washing of the roots has a beneficial effect, and to this in a great measure must be ascribed the fertilising effects of pure and soft running water. But besides this washing of roots, there is the constant feeding of them, which is the more probable explanation of the fertilising influence of that constant current of water among them which is produced in drained and in irrigated land.

If water stagnates and is evaporated, and the noxious matter held in solution remains in the soil, all the advantage of irrigation is lost, and the better kinds of grasses are succeeded by rushes and coarse aquatic plants, as may be seen in all marshy spots. The circulation of the water therefore appears to be as necessary as its presence; and, provided there be a sufficient supply of water of a proper quality, the more porous is the soil, and especially the subsoil, the more vigorous is the vegetation. It is on this principle alone that we can rationally account for the great advantage of irrigation in those climates where rain is abundant, and where the soil, which is most benefited by having a supply of water running through it, is of a nature to require artificial draining as an indispensable preliminary to being made fertile by irrigation. By keeping these principles in view great light will be thrown on the practical part of irrigation, which, having been long established by experience before these principles were thought of, depends not on their correctness, but only confirms their truth.

The whole art of irrigation may be deduced from two simple rules, which are, first, to give a sufficient supply of water during all the time the plants are growing, and secondly, never to allow it to accumulate so long as to stagnate. We shall see hereafter one apparent exception to this last rule, but it will be readily explained.

The supply of water must come from natural lakes and rivers, or from artificial wells and ponds, in which it is collected in sufficient quantity to disperse it over a certain surface. As the water must flow over the land, or in channels through it, the supply must be above the level of the land to be irrigated. This is generally the principal object to be considered. If no water can be conducted to a reservoir above the level of the land, it cannot be irrigated. But there must also be a ready exit for the water, and therefore the land must not be so low as the natural level of the common receptacle of the waters, whether it be a lake or the sea, to which they run. The taking of the level is therefore the first step towards an attempt to irrigate any lands.

Along the banks of running streams nature points out the declivity. A channel, which receives the water at a point higher than that to which the river flows, may be dug with a much smaller declivity than that of the bed of the river, and made to carry the water much higher than the natural banks. It may thence be distributed so as to descend slowly and water a considerable extent of ground in its way to rejoin the stream. This is by far the most common mode of irrigation; and the shape, size, and direction of the channels are regulated by the nature of the surface and other circumstances, which vary in almost every situation. A few examples will give to those who are not acquainted with the best modes of irrigating land a pretty accurate notion of the system.

We shall suppose a river to run with a rapid current between high banks. At some point of its course a portion of the water is diverted into a canal dug along the bank, with a very small declivity. The water in this canal will flow with less rapidity than the river, keeping nearly the same level as that part of the river where it has its origin. Thus the water may be carried over lands which are situated considerably above the bed of the river farther down. All the lands between this canal and the river may be irrigated if there is a sufficient supply of water. The canal may be carried to a considerable distance from the river. The size of the canal and its declivity depend on the quantity of water which may be made to flow into it. A dam is often constructed across a river, in order that as much of its water as is possible may be diverted, and the original channel is often laid quite dry, to take advantage of all the water at the time when it is advantageous to irrigate the land. To have an entire command of the water there are flood-gates on the main channel and on the lesser branches. By opening or shutting these the water may be stopped or made to flow as may be required. It must be remembered, that to carry water to a considerable distance, and in great quantity, a larger channel and more rapid declivity are required; and it is a matter of calculation whether it is most advantageous to bring a smaller quantity to a higher point, or a greater abundance somewhat lower. Having a certain command of water, it may be carried from the main channel by smaller branches to different points, so as to irrigate the whole equally. These branches should be nearly horizontal, that the water may overflow the sides of them, and be equally distributed over the land immediately below. Every branch which brings water over the land should have a corresponding channel below to carry it off; for the water must never be allowed to stop and stagnate. When it has run 15 or 20 feet, according to the declivity, over the land situated below the *feeder*, or the channel which brings the water, it should be collected into a drain to be carried off, unless it can be used to irrigate lands which lie still lower. Finally it runs back into the river from which it was taken, at a lower point of its course.

When there is a considerable fall and a sufficient supply of water, a series of channels may be made, so situated below each other, that the second collects the water which the first has supplied, and in its turn becomes a feeder to irrigate the lower parts of the declivity: a third channel receives the water and distributes it lower down, until the last pours it into the river. This is called *catch work*, because the water is caught from one channel to another. This method is only applicable where there is a considerable fall of water and a gentle declivity towards the river. But it must be borne in mind that the water is deteriorated for the purpose of irrigation, when it has passed over the land, and that it is not advantageous to let it flow over a great extent when a fresh supply can be obtained: but where only a small portion of water can be commanded, that must be made the most of; and it will irrigate three or four portions of land in succession without there being any very marked difference in the effect: beyond this it rapidly loses its fertilising qualities. This is not owing to the water having deposited the fertilising substances which it held in solution, or which were diffused through it, but to its having taken up some substances which are detrimental to vegetation, and being saturated with them: at least this is the most probable opinion when all circumstances are taken into the account.

The general principle of irrigation may be described as the supplying every portion of the surface with an abundance of water, and taking it off again rapidly. In many situations the great difficulty in irrigation arises from the want of a supply of water; but even then a partial irrigation may be effected, which, although not perfect, will have its advantages. A small rill which is often quite dry in summer may still, by judicious management, be made to improve a considerable portion of land: its waters may be collected and allowed to accumulate in a pond or reservoir, and let out occasionally, so that none be lost or run to waste. If there is but a small quantity it must be husbanded and made to flow over as great a surface as possible. If there is water only at particular seasons of the year, and at a time when it would not be of much use to the land, it may be kept in ponds, and it will lose none of its qualities by being exposed to the air. If animal or vegetable matter in a partial state of decomposition is added to this water, it will much improve its quality, and by a judicious distribution of it over the land a great benefit may be obtained.

If there is not a want of water, there may be a want of declivity to enable it to flow off, which, it should always be remembered, is an essential part of irrigation. Art may in this case assist nature by forming a passage for the water, either in its course towards the land to be irrigated, or from it after it has effected its purpose. Where there is no natural exit, and it might lead to too great an expense to make an artificial one, the water may sometimes be led into shallow ponds, where a great part is evaporated; or porous strata may be found by boring, into which it can be made to run and be dispersed. Along rivers where the fall is very imperceptible a channel brought from a considerable distance may give such a command as to throw the water over a great extent of surface; and to carry it off another channel may be cut, emptying itself at some distance below: so that lands which lie along the banks of a river may be irrigated, although they are actually below the level of the river, and require banks to protect them from inundation.

When the surface to be irrigated is very flat and nearly level, it is necessary to form artificial slopes for the water to run over. The whole of the ground is laid in broad beds, undulating like the waves of the sea. The upper part of these beds is quite level from end to end, and here the channel which brings the water is cut. From the edge of this channel the ground is made to slope a foot or two on both sides, and a ditch is cut at the bottom parallel to the float. The whole of the ground is laid out in these beds. All the supply furrows are fed by a main channel at right angles to the beds and somewhat above them, and all the ditches or drains run into a main ditch parallel to the main float, and below the lowest drain. The course of the water is very regular. As soon as the flood-gates are opened it flows into all the upper channels, which it fills till they overflow in their whole length. The sloping sides are covered with a thin sheet of running water, which the lower drains collect and carry into the main ditch.

Experience has shown that there are particular seasons when the water has the best effect; a perfect command of it is therefore indispensable, and also a regular supply. During frost, when all dry meadows are in a state of torpor, and the vegetation is suspended, the water-meadows, having a current of water continually flowing over them, are protected from the effect of frost, and the grass will continue to grow as long as the water flows over it. Too much moisture however would be injurious, and the meadows are therefore laid dry by shutting the flood-gates, whenever the temperature of the air is above freezing. By this management the grass grows rapidly at the first sign of spring. Before the dry upland meadows have recovered the effects of frost and begun to vegetate, the herbage of the water-meadows is already luxuriant. As soon as they are fed off or cut for the first crop of hay, the water is immediately put on again, but for a shorter time; for the warmer the air, the less time will the grass bear to be covered with water. A renewed growth soon appears, and the grass is ready to be cut a second time when the dry meadows only give their first crop. Thus, by judicious management, three or four crops of grass are obtained in each season, or only one abundant crop is made into hay, and the sheep and cattle feed off the others. The usual way in which the grass of water-meadows is made profitable is by feeding ewes which have early lambs till the middle of April. A short flooding soon reproduces a crop, which is mown for hay in June; another flooding gives an abundant aftermath, which is either mown for hay, or fed off by cows, bullocks, and horses; for at this time the sheep, if pastured in water-meadows, are very subject to the rot. The value of good water-meadows could scarcely be believed by those who are not familiar with them. Where the water is suited to irrigation they never require manuring. Their fertility is kept up continually, and the only attention required is to weed out coarse aquatic plants, which are neither nutritious nor wholesome in hay or pasture.

The best soil for a water-meadow is a good gravel. The finest water-meadows on the Avon in Wiltshire, where the richest herbage is found, have scarcely any soil at all, but are on little more than a bed of shingle matted together by the roots of the grass, which proves that the waters of the Avon contain all the principles essential to rapid vegetation. Great attention is required, and some experience, to irrigate meadows, so as to give the greatest profit.

In hot weather, when we should imagine that the land must be thirsty, and that too much water cannot be poured over it, much mischief may be done by injudicious flooding. In winter, on the contrary, the land may be covered with water for weeks without injury; and if an earthy deposit takes place, the subsequent fertility is greatly increased. But this is not properly irrigation: it is inundation, and the effects depend on entirely different causes. When low meadows are inundated in winter and spring, it is the muddiness of the water which enriches the land: a fine layer of extremely divided matter is deposited, and when the water subsides this acts as a coat of manure.

Water may be carried in small channels through meadows without being allowed to overflow, and in this case the effect is similar to that caused by rivers or brooks which wind slowly through valleys, and produce a rich verdure along their course. This is watering, but not properly irrigating. When this is done judiciously, the effect is very nearly the same as when the land is irrigated; and in hot climates it may be preferable, by giving a constant supply of moisture to the roots, while the plants are growing. The great advantage of water-meadows in England is not so much the superior quantity of grass or hay which is obtained when they are mown, as the early feed in spring, when all kinds of nutritive fodder are scarce. When the turnips are consumed before the natural grass or the rye sown for that purpose is fit to be fed off, the water-meadows afford abundant pasture to ewes and lambs, which by this means are brought to an early market. The farmer who has water-meadows can put his ewes earlier to the ram, without fear of wanting food for them and their lambs in March, which is the most trying season of the year for those who have sheep. At that time an acre of good grass may be worth as much for a month as a later crop would for the remainder of the year.

When it is intended to form a water-meadow on a nearly level surface, or where a fall of only two or three feet can be obtained in a considerable length, the whole of the land must be laid in beds about 20 or 30 feet wide, the middle or crown of these beds being on a level with the main feeders, and the bottoms or drains on a level with the lower exit of the water, or a little above it. To form these beds most expeditiously, if the ground is already in grass, the sod may be paired off and relaid after the beds are formed, by which means the grass will be sooner re-established; but except in very heavy soils, where the grass is some time in taking root, the easiest and cheapest way is to plough the land two or three times towards the centre, and dig out the drain with the spade: the earth out of the drains, and that which is taken out of the upper trench or feeder, may be spread over the bed to give it the proper slope. A roller passed over the bed in the direction of its length will lay it even, and the seeds of grass being sown over it, the water may be let on for a very short time to make them spring. As soon as the grass is two or three inches above ground a regular flooding may be given, and in a short time the sward will be complete. Instead of sowing seed, tufts of grass cut from old sward may be spread over the newly formed beds, and they will soon cover the ground. The Italian rye-grass, for instance, grows so rapidly, that if it be sown in February, or as soon as the snow and frost are gone, it will afford a good crop to feed off in April, or to mow for hay by the beginning of May; and after that it may be cut repeatedly during the summer. But where the soil is good and the water abundant, good natural grasses will spring up without much sowing, and soon equal the old water meadows.

It seems essential to the formation of a good water-meadow that the bottom be porous and free from stagnant water; hence underdraining is often indispensable before a water-meadow can be established: and a peat-bog, if drained and consolidated, may have water carried over its surface, and produce very good herbage. If the soil is a very stiff clay, draining is almost indispensable where a water-meadow is to be made. The more porous the soil the less depth of water is required, which is not obvious at first sight; but the clay lets the water run over the surface without soaking into the roots, whereas the porous soil is soon soaked to a considerable depth. The water must therefore be longer on the clay than on the sand or gravel to produce the same effect. If the water is properly applied all kinds of soils may be converted into fertile water-meadows. On very stiff clays a coat of sand or gravel, where it can be easily put on, will greatly improve the herbage. It should not be ploughed in, but laid on the surface two or three inches thick: chalk will also improve the herbage.

The usual time of letting on the water on water-meadows is just before Christmas, and it may continue to flow over the land as long as the frost lasts, unless the frost be very severe and the land be frozen: in mild weather it may be turned off during the day and put on again at night until the frost is gone. The grass will soon begin to grow, and be ready to be fed off. When this is done the water is immediately let on for a short time, and turned off again to allow the ground to dry after a few days' flooding, and the water is let on again at short intervals. The warmer the air is, the shorter time must the water be allowed to cover the meadows. As soon as the grass is five or six inches long it must be left dry entirely till it is mown or fed off.

In summer the floodings must be very short; seldom more than twenty-four hours at a time, but frequent. Thus a great weight of grass may be obtained year after year without any manure being put on the land, care being taken that where the surface is not quite even the hollows be filled up with earth brought from another place, or dug out of the drain, if that should be partially filled up with the soil which the water has carried into it. We alluded before to a case where water may remain a considerable time on the land without injury; this is, when there are inundations from rivers, which rise above their beds in spring and cover the low meadows which lie along their banks. In this case the grass, which has not yet sprung up, is protected from the cold, and if there be a deposit from the water there is a considerable advantage. But when it subsides, it must be made to run off entirely, without leaving small pools, by which the grass would inevitably be injured. Small ditches or channels are usually dug, by which all the water may run off, unless where the subsoil is very porous, or the land is well under-drained, which is seldom the case in these low meadows, for the drains would be apt to be choaked by the earthy deposit from the water. These inundations can sometimes be regulated by means of dykes and flood gates, in which case they partake of the advantages of irrigation, and also of that deposition of fertilising mud which is called warping. [WARPING.]

At a lecture given before the English Agricultural Society, at their Salisbury meeting, Mr. J. Combes, of Tisbury, made the following statement on the management of two Devonshire and Wiltshire meadows; and we quote it as he is probably the first authority on this subject in England :—

"The watering should commence the first week in November, by which time there will be a crop of young grass about two inches high. It is very desirable to have the young grass when the watering begins, that the water may percolate through the grasses so as not to flood them, otherwise they will, if flooded for any length of time, be stifled and become thin. The meadows should always be in readiness to receive the first fresh of the river from the autumnal rains, as this water is, especially after a dry summer, rich with alluvial matter. Many meadows are very much injured by being fed too late in the season, and by the treading of cattle; it should always be borne in mind that one mouthful of water-meadow grass in April is worth five or six of the same when fed in November. In general, the more the land is watered in November and December the better; but should the weather be very mild during this time, the meadows may have a few days' drying. In January the water should remain on the land about five days in six, unless the frost be so intense as to cover the meadows with ice, which is sometimes the case, when the water should be all turned off the land until a thaw takes place; the young grass will be protected by the ice and even grow under it. In February three days in four will be enough for watering. In March the irrigation should be two days in four until the water is turned out to make the land dry for feeding the grass, which will generally be fit about the last week. As soon as the sheep have fed off a portion of the meadow, or about the middle of April, the water should be again turned over that portion, but care must be taken not to allow it to remain long on the land until the grass be grown high enough to keep above the water; during the remainder of this month and the following months of May and June, two days in a week will be enough for watering. In general the grass will be fit to cut for hay by the middle of June. In July and August, or until the second hay crop be fit to cut, the water should be used sparingly, one day in six will be quite sufficient. In September and October water-meadows should be kept perfectly dry. The above rules apply to meadows that have a plentiful supply of water, but on those meadows that are short of water, which are by far the greater part, some of them requiring to be watered in five or six portions, technically called sterns, the whole of the water should remain on each stern for about five days at a time in winter, and two days at a time in summer, so that all the meadow may be watered in about twenty or thirty days in winter, and eight or ten in summer. A good flow of water, or what is called thick watering, is always to be preferred to thin watering, especially during the summer months; for a very thin watering for a week together at summer time, especially on a clay soil, is oftentimes injurious. I may here remark that night watering is preferable to watering by day, and the water will do more good in shady than in sunny weather. The water of the streams in this part of the country runs from the chalk, the upper green sand, and the upper oolite formations. That best adapted for irrigation is pure spring water.

"All water is very good for irrigation wherein certain aquatic plants grow, such as brooklime, watercresses, and water mill-foil, and when stones and other substances in the stream are thickly covered with lichen. Some of the best descriptions of grasses for water meadows are—*Anthoxanthum odoratum*, or sweet-scented vernal grass; *Festuca pratensis*, or meadow fescue grass; *Phleum pratense*, or Timothy grass; *Lolium perenne*, or rye-grass; *Agrostis stolonifera*, or fiorin grass. All these are found in the best of the Wiltshire water-meadows, especially the Timothy and fiorin grasses. I should recommend in all new water-meadows a mixture of Italian rye-grass. I will now state what may be considered the average produce of the water-meadows in South Wilts. In doing so I will take a meadow of 20 acres, depastured in spring by sheep. The spring feed of this meadow as fed in April will keep 400 couples of sheep 25 days, during which time these 400 couples will fold 10 acres of arable land, and it will after this yield in the first and second cuttings of grass about 40 tons of hay. As I have said, this may be considered the average production of these water meadows. But in order to see the capabilities of some of the best description, I will here state the annual average produce of some of them. In showing this, I will again take a 20-acre meadow, the spring grass of which, when fed by sheep from about the last week in March till the middle of May, will keep 400 couples seven weeks. During this time these couples will fold in the arable land from 15 to 20 acres. This meadow will then in two cuttings give at least 60 tons of hay. In this case there is annually put on the arable land 15 acres of spring folding and 60 tons or more of hay, thus enabling the farmer to dispense with the growing of about 20 acres of turnips and about 25 acres of field grass, or to increase the number of his sheep stock on a farm of 400 or 500 acres at least 12 per cent. I have myself, on a meadow of 13a. 3r. 26p., kept on the spring grass, in April and May, 277 couples 33 days, and 11 cows 26 days, with a little less than 10 lbs. of hay per day per cow, after which there was cut from the same meadow at least 2 tons of hay per acre, the aftermath being fed by cows and horses. I have also mown part of a water-meadow 29 times in six consecutive years, the produce of which averaged annually during the six years a little more than 40 tons of grass per acre; one year it produced more than 47 tons. In some seasons, when there is a failure of the turnip crop, the spring feed of water-meadows is exceedingly valuable; I have known it frequently let for 7*l.* or 8*l.* per acre, and in one instance I knew the spring feed of a water meadow of 6½ acres let for 80*l.*, or nearly 13*l* per acre."

On the proper seeding of land intended for a water-meadow, we quote Professor Tanner's report on the Practice of Irrigation in the 'Journal of the Bath and West of England Agricultural Society.' The following is his list :—

"*Poa aquatica* (or *Glyceria aquatica*). This water-meadow grass, also known as the reedy sweet-water grass, is a valuable plant for irrigated land, as it has a *rapid growth of good quality*.

"*Poa fluitans* (or *Glyceria fluitans*), floating sweet-water grass, is exceedingly *early* in its growth, and for this reason is generally sought after in seeding new meadows.

"*Poa trivialis*, rough-stalked meadow-grass, although not particularly early, is yet *productive*, and very desirable for water-meadows.

"*Agrostis stolonifera*, fiorin grass or marsh bent, takes a high position as a water-meadow grass. It is very productive, and yields *both early and late* herbage of good quality. It always *spreads* rapidly, and maintains a firm plant.

"*Alopecurus pratensis*, meadow foxtail grass. Its *early*, *abundant*, and *rapid growth*, together with the excellent qualities of the herbage, place this among our best grasses for meadows; and it answers very well for water-meadows, *provided* the management is good.

"*Festuca elatior*, tall meadow-fescue. This grass, although rather coarse in its nature, is *relished by stock*; it is, however, best suited to land which lies low.

"*Festuca pratensis*, meadow-fescue. The produce is *abundant* without being coarse; the *quality* is *excellent*, and its growth regular.

"*Lotus major*, great bird's-foot trefoil. Moist situations are its natural localities. It yields an *abundance of nutritious food*, and is much sought after by stock.

"*Trifolium hybridum*, hybrid clover, is not grown as much as its merits justify; it is highly esteemed on the Continent, and where it is grown in this country it answers very well. It is the *most suitable of all the clovers* for a water-meadow.

"*Phleum pratense*, meadow cat's-tail or Timothy grass. The growth of the grass is *both early* in the spring *and late* in the winter; it produces an abundance of herbage, and the *quality is exceedingly good*.

"These are the principal grasses which are suitable for irrigated land; and the following mixture of these seeds, which has been recommended,* appears to be a judicious receipt :—

	lbs.
Agrostis stolonifera	2
Alopecurus pratensis	2
Festuca elatior	2
„ pratensis	2
„ „ loliacea	2
Glyceria aquatica	1
„ fluitans	2
Lolium italicum	8
„ perenne	12
Phalaris arundinacea	2
Phleum pratense	2
Poa trivialis	3
Lotus major	2
Trifolium hybridum	1
	43

"These seeds should be sown on the land after it has been well cleaned and brought into good order by previous cultivation. The surface must be gently harrowed and then rolled, the birds kept off, and with ordinary care a good plant of grass will soon establish itself, producing herbage of the very best quality."

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* Morton's 'Encyclopædia of Agriculture,' vol. i. p. 1001.

Lastly, we quote Professor Buckman's report on the influence of irrigation in modifying or improving the character of natural pasturage. He says:—

"Irrigation, when it can be practised, is—though acting indirectly—the most direct means of getting rid of all extraneous plants from grass herbage, and the most direct encourager of the growth of grass solely that we possess; in illustration of which we quote the subjoined table from the 'Journal of the Royal Agricultural Society,' vol. xv., part 2.

TABLE I.—SHOWING THE CHANGE OF HERBS (NOT GRASSES) UNDER IRRIGATION.

Botanical Names.	Common Names.	Proportionals.		
		Before Irrigation.	After two years' Irrigation.	After four years' Irrigation.
Ranunculus acris .	Upright Meadow Crowfoot .	1	3	1
,, bulbosus	Bulbous Crowfoot . .	3	1	..
Plantago lanceolata .	Narrow-leaved Plaintain .	3	1	1
,, media . .	Broad-leaved Plaintain . .	3	..	..
Trifolium repens .	Dutch Clover . . .	2	..	..
,, pratense .	Broad Clover . . .	1	2	2
Anthriscus vulgaris .	Common beaked Parsley .	1	2	1

"Here we see a marked decrease in bad plants and a corresponding increase in good to be distinctly traced in two years; and in four years this decrease is still more rapidly progressing; and we are enabled to state, as the result of some seven years' watching, that now the irrigated meadow presents scarcely a trace of the plants belonging to this table, but all, or nearly all, are replaced by most excellent grasses.

"The following table represents the changes which took place in twelve species of the meadow-grasses in the same time. This field trebled in value in four years, and is now worth 5*l.* an acre, its increased value being due not only to the fact of its growing grass and nothing else, but to its growing only the best kinds of grasses; for irrigation acts indirectly by killing weeds and innutritious grasses.

TABLE II.—REPRESENTING THE CHANGES OF GRASSES UNDER IRRIGATION.

Botanical Names.	Common Names.	Proportionals.		
		Before Irrigation.	After two years' Irrigation.	After four years' Irrigation.
Alopecurus pratensis .	Meadow Fox-tail Grass . .	1	2	4
Poa pratensis . .	Field Meadow Grass . .	2	3	4
,, trivialis . . .	Rough Meadow Grass . .	1	2	1
Briza media . .	Quaking Grass . . .	2	..	..
Cynosurus cristatus .	Crested Dog's-tail Grass .	2	1	..
Aira cæspitosa. . .	Hassock Grass . . .	1	..	..
Agrostis stolonifera .	Marsh Bent Grass . .	1	2	3
Dactylis glomerata .	Cock's-foot Grass . . .	1	2	3
Avena flavescens . .	Yellow Oat Grass . .	2	3	3
,, pubescens .	Soft Oat Grass . . .	1	1	1
Hordeum pratense .	Meadow Barley Grass .	1	2	2
Lolium perenne . .	Perennial Rye-grass . .	2	4	6

"These tables will at a glance show the practical bearing of irrigation as an indirect means of getting rid of extraneous meadow plants, and at the same time its direct advantage in encouraging the growth of grasses."

ISAMIC ACID. [INDIGO.]

ISAMIDE. [INDIGO.]

ISATANE. [INDIGO.]

ISATHYD. [INDIGO.]

ISATIC ACID. [INDIGO.]

ISATILIME. [INDIGO.]

ISATIMIDE. [INDIGO.]

ISATIN. [INDIGO.]

ISATINIC ACID. [INDIGO.]

ISATYDES. [INDIGO.]

ISETHIONIC ACID is one of the substances found in the residue from the preparation of ether, but may be formed directly by boiling, for some time, a strong solution of ethionic acid. The formula for ethionic acid is (C_4H_4,2HO,4SO_3);—not (C_4H_4,2HO_3,4SO_3) as represented under ETHIONIC ACID—and by ebullition is decomposed into sulphuric and isethionic acids: these may be separated from each other by neutralisation with carbonate of baryta and the isethionate of baryta obtained in tabular crystals by evaporation of the filtered solution.

Isethionic acid (C_4H_4,2HO,2SO_3) is uncrystallisable. It is isomeric with sulphovinic acid, but is well characterised by the greater stability of its salts. The general formula of the *isethionates* is (C_4H_4,HO,MO,2SO_3) or perhaps (MO,$C_4H_5S_2O_7$). They are mostly crystallisable, and when heated with hydrate of potash are decomposed into carbonate, oxalate, sulphate and sulphite of the base, hydrogen being evolved.

ISINGLASS is animal jelly, or gelatin, nearly pure. The best isinglass is prepared in Russia from the membranes of the sturgeon, especially from its air-bladder and sounds, which are remarkably large. These, when removed from the fish, are washed with cold water, and exposed a little to the air, in order that they may stiffen; the outer skin is then taken off and rejected, and the remainder cut out, and loosely twisted into rolls, according to the intended size of the pieces, which are called *staples*, and are known in commerce by the names of long and short staple, and of these the first is the best: these are dried in the air. The best sort of isinglass is used for the table and in confectionary; it is also largely employed in refining wine and beer.

Isinglass is nearly colourless, has but little taste or smell, is translucent in thin pieces, and is soluble in water. One part of it dissolved in 100 parts of hot water gives a solution which completely stiffens in cooling.

Isinglass is also dissolved by most acids readily, and also in solution of potash and soda, but not in alcohol. Several metallic salts and oxides have the property of precipitating a solution of isinglass, but corrosive sublimate does not produce this effect, which serves to distinguish it from albumen; but it resembles that substance in being precipitated by infusion of galls or of oak-bark. Isinglass is extremely nutritious.

The degree in which we are dependent on different countries for our supply of isinglass will be seen by the following figures, which refer to the importations for 1856, presenting a fair average for recent years:—From Russia, 525 cwts.; Brazil, 440; East Indies, 233; Prussia, 166; Guiana, 87; other countries, 170; equal in the whole to about 180,000 lbs.

ISIS, one of the chief deities of the Egyptians, the sister and wife of Osiris. Isis was the Goddess of the Earth; the Universal Mother; the Goddess of Fecundity, and the cow was therefore sacred to her. In the later dynasties she was the divinity of the moon, Osiris being that of the sun. By the Greeks she was identified with Demeter, and her worship became widely spread through Greece, and subsequently in Rome. She was said to have first taught men the art of cultivating corn, whence corn was always carried in processions at her festivals. The annual festival of Isis in Egypt lasted eight days, during which a general purification took place. The priests of Isis were bound to observe perpetual chastity, their heads were shaved, and they went barefooted. The goddess was often represented as a woman with the horns of a cow. She also appears with the lotus on her head and the sistrum in her hand; and her head in some instances is seen covered with a hood. Heads of Isis are a frequent ornament of Egyptian capitals on the pillars of the temples, as in the façade of the temple of Denderah, and the column from the same building, both engraved under EGYPTIAN ARCHITECTURE, where also the female figures shown in the cut of the temple of Abou-Sambul are supposed to be representations of Isis.

As the worship of Isis passed into foreign lands it assumed a foreign character and many foreign attributes, as we see from the Greek and Roman writers. Sometimes Isis is represented like Diana of Ephesus, as the universal mother, with a number of breasts. The mysterious rites of Isis were probably in their origin symbolical: on one of her statues was the inscription, "I am all that has been, that shall be; no mortal has hitherto taken off my veil." But the Isiac rites, transplanted to Italy, became a cloak for licentiousness, and they were repeatedly forbidden at Rome. Tiberius had the images of Isis thrown into the Tiber, but the worship revived, and Juvenal speaks of it in an indignant strain. The Isiac table in the Turin Museum, which is supposed to represent the mysteries of Isis, has been judged by Champollion to be the work of an uninitiated artist, little acquainted with the true worship of the goddess, and probably of the age of Hadrian.

(Plutarch's *Treatise on Isis and Osiris*, Wyttenbach's ed., ii. 441; Herod., ii. 41, 42, 123, &c.; Pausan., ii. 13, 7, and particularly x. 32, 13; Rosellini; Wilkinson, *Ancient Egyptians*, vol. iv.)

ISOCETAMIDE. [ISOCETIC ACID.]

ISOCETIC ACID ($C_{30}H_{30}O_4$). The grains of several euphorbiaceous plants yield by expression a white inodorous oil of sp. gr. ·91. By saponification with caustic soda it is separated into oleic and isocetic acids. The latter purified by crystallisation from alcohol is obtained in brilliant plates, the melting point of which is 131° Fahr.

Isocetamide ($C_{30}H_{31}NO_2$) results when the oil is heated with ammonia in a closed tube. It is a white substance fusible at 152° and not acted upon by concentrated caustic potash.

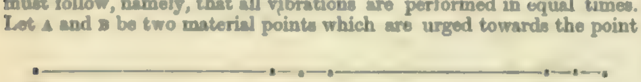
Isocetic ether is a white odourless body, solid at temperatures below 0° Fahr. [ETHEREAL SALTS.]

ISOCHROMATIC LINES are those coloured rings which appear when a pencil of polarised light is transmitted along the axis of a crystal, as mica or nitre, and is received in the eye after passing through a plate of tourmaline. If a plate of nitre, having its surfaces perpendicular to the axis of the natural prism, and highly polished, be placed between two plates of tourmaline having their axes at right angles to one another, and the system be held close to the eye, which is directed towards the sky or a sheet of white paper, there will be seen a series of oval rings, about each of two points as poles, forming together figures resembling *lemniscates*, which are curves defined by the property that the rectangle contained by two lines drawn from two points called the poles to any point in the curve is constant. The light coming directly from a lamp or candle may be used in the experiment, provided a lens of short focus be added in front, so as to condense the light on to the system, and thus furnish an illuminated field of sufficient angular extent to comprise the rings.

The curves receive their designation from the circumstance that throughout each the tint is constant. For nitre, and other biaxal crystals whose optic axes are not far apart, the tint is determined by the value of a quantity varying directly, in a given kind of crystal, as the rectangle above mentioned (the distance between the poles being supposed constant), and inversely as the thickness of the crystalline plate. In the general case, the curves are conceived to exist on the surface of a sphere of which a point in the crystal is the centre; and when the optical axes of the crystal are at a considerable distance from one another, if the curves be projected on a plane, the tint in each curve will depend on the product of the sines of the angles subtended by two lines drawn from the poles to a point in its periphery, and also upon the length of the path described by a ray of light in passing through the crystal.

ISOCHRONOUS, ISOCHRONISM (ἴσος, equal, χρόνος, time). Vibrations or oscillations which are performed in equal times are called isochronous; and isochronism is the name given to a remarkable property of all systems which are in equilibrium, namely, that when slight disturbance, be the same more or less, is given, the oscillations which take place are all performed in the same time, or so nearly in the same time, that any acceleration or retardation is totally imperceptible. Thus, when a pendulum is allowed to vibrate till it rests, it will be found that there is no perceptible difference between the vibrations of longer and shorter extent; of which any reader may satisfy himself by attaching a weight to a string, and observing the vibrations. But a still better proof may be found in a musical string: the finest ear cannot detect any difference between the pitch of a note made by a smart blow on the key of a pianoforte and that made by a gentle one; yet a very small difference in the number of oscillations per second would be perceptible, and the amount of disturbance from the position of equilibrium is twenty or thirty times greater in the first case than in the second.

When, under two different circumstances, the longer space is described in the same time as the shorter, it must be that the force acting in the first case is greater than that in the second; and it is sufficiently known from experience, that the more a system at rest is disturbed, the greater is the effort which it makes to return. But in order that there may be isochronism, it is not sufficient that the effort to return should increase with the amount of disturbance, but the increase must take place according to one particular law. This law is as follows:—the force of restitution must be always proportional to the disturbance, so that whatever force begins to act when the disturbance is a, twice as much acts when the disturbance is twice a; and so on for all proportions. That this law does prevail when the disturbance is not great, either absolutely, or so nearly that its error is extremely small, may be proved both by theory and experiment. The most complete proof is to be found in the 'Mécanique Analytique' of Lagrange. Granting the law, we can make it sufficiently apparent that the consequence must follow, namely, that all vibrations are performed in equal times. Let A and B be two material points which are urged towards the point O by pressures which are proportional to OA and OB; and further let each pressure diminish as either point approaches towards O, so as always to preserve between the pressures at any two points the proportions of the distances of those points from O. Take a minute portion of time, so small that the pressure may not vary sensibly during its continuance: then [Acceleration; Fall of Bodies] the velocities created and the spaces described in that time will be proportional to the pressures producing them. If then, during that time, A move to K and B to Q, AK and BQ (and therefore OK and OQ) will be in the proportion of OA to OB, and the points will be at K and Q, with pressures and velocities proportional to OK and OQ. In a second such instant let the points move to L and R: then KL and QR, partly due to velocities which are as OK to OQ, and partly to accelerations which are in the same proportion, will still be in the proportion of OK to OQ, or of OA to OB. Consequently the whole AL is to the whole BR in that proportion: and reasoning in this way for successive small accelerations, we show that the whole space moved over by A in any time is to that moved over by B in the same time in the proportion of OA to OB. Consequently A describes AO in the same time in which B describes BO; or the half of a vibration of A is made in the same time as half a vibration of B.



To make this process perfectly strict, recourse must be had to the considerations in Integral Calculus.

ISOCLINAL. A term applied to those lines on the surface of the globe which connect places where a magnetic needle has the same inclination or dip. The term means *equal inclination*, just as Isodynamic means *equal force*; isodynamic lines connecting those places where the total magnetic power of the earth is the same. [Magnetism, Terrestrial.]

ISOCYANURIC ACID. [Fulminuric Acid.]

ISOMERISM. There are numerous substances, especially amongst organic compounds, which contain the same elements in exactly the same proportions, but which nevertheless differ more or less widely from each other in their properties. Such substances are said to be *isomeric*, and this property or attribute is termed *isomerism*. A striking instance of this relation between a number of compounds is seen in cyanic acid and its *isomers*. Thus the following compounds, though widely different from each other in properties, all possess the same percentage composition:

Cyanic acid	C_2HNO_2
Cyamelide	C_2HNO_2
Fulminic acid	$C_4H_2N_2O_4$
Fulminuric acid	$C_6H_3N_3O_6$
Cyanuric acid	$C_6H_3N_3O_6$
Cyanilic acid	$C_6H_3N_3O_6$

When two or more isomeric compounds have the same equivalent number, as cyanic acid and cyamelide in the above list, they are said to be *metameric*. In some cases where the equivalent numbers of isomeric compounds differ, and where it may be supposed that the difference in properties results simply from the different state of condensation of their elements, as in the olefiant gas family, the bodies are said to be *polymeric*.

ISOMETRICAL PERSPECTIVE. [Perspective.]

ISOMORPHISM. This term, employed in chemistry and crystallography, strictly signifies similarity of form, but chemists restrict the term to such bodies as are not only similar in crystalline form but also in chemical composition; thus diamond, magnetic oxide of iron, and alum, all possess the same crystalline form, that of the octohedron—but they are not regarded as isomorphous, because they possess no analogy in chemical composition. On the other hand spinelle-ruby (MgO,Al_2O_3), magnetic oxide of iron (FeO,Fe_2O_3), and chrome iron ore (FeO,Cr_2O_3) are termed isomorphous because they not only crystallise in the same form, but are analogous in their composition. The following are some of the most important isomorphous groups:—

I.

Alumina	Al_2O_3
Sesquioxide of iron	Fe_2O_3
Oxide of chromium	Cr_2O_3
Ilmenite	$FeTiO_3$

II.

Sulphuric acid	SO_3
Selenic acid	SeO_3
Chromic acid	CrO_3
Manganic acid	MnO_3

III.

Chloride of potassium	KCl
Bromide of potassium	KBr
Iodide of potassium	KI
Fluoride of potassium	KF

For further details regarding isomorphism, and also for a description of the doctrine of *dimorphism*, see Miller's 'Chemical Physics.'

ISOPERIMETRICAL. [Variation, Calculus of.]

ISO'SCELES (ἴσος, equal, σκέλος, leg, the *c* usually pronounced hard, like *k*), a term applied to a triangle of which two sides (or legs) are equal.

ISOTARTARIC ACID. [Tartaric Acid.]

ISOTEREBENTHIN. [Turpentine.]

ISOTHERMAL LINES. [Meterorology; Temperature, Terrestrial, Distribution of.]

ISSUE. (Law.) [Pleading.]

ISSUE is an ulcer artificially formed for the purpose of maintaining a constant purulent discharge from some part of the body. It is usually made by placing one or more beads or peas on an incision through the integuments in one of the limbs, or in the neighbourhood of a diseased part, and there retaining them by adhesive plaster, so as to prevent the wound from healing, and keep it in a constant state of suppuration. Other issues are made by rubbing caustic potash, or potash and quicklime, on a part of the skin till it is destroyed and sloughs, and by keeping open the ulcer thus formed, either with peas, or very stimulant dressings. Setons are another form of issue, made by passing a broad flat needle beneath a portion of the skin, and retaining in the passage thus formed either a skein of silk or a flat band of caoutchouc. The moxa and the actual cautery are also sometimes employed with the same view.

The use of issues for the cure of constitutional diseases, under the idea that they remove noxious principles from the blood, is now entirely abandoned; but they are sometimes had recourse to in order to restore an habitual discharge which has been checked by the cure of any chronic local particularly skin disease, and the cessation of which has seemed to give rise to congestion of the head or of any internal organ. But the principal value of issues is as counter-irritants, by establishing a disease which is of itself unimportant in the neighbourhood of one which by its situation is more serious; and hence they are amongst the most important means in the cure of chronic inflammations of many internal organs, and especially of those of the joints and of the spine.

ISSUE PEAS are round bodies employed for the purpose of maintaining irritation in a wound of the skin which is called an issue. [ISSUE.] It is a matter of indifference of what substance the peas are composed, so long as they do not introduce poisonous matters into the wound. The seed of the common garden pea is frequently used; but this is apt to putrify or sprout. It is however more common to use the young unripe fruits of the common orange (*Citrus aurantium*). The fruits are dried and afterwards turned in a lathe before they are used as issue peas. The unripe oranges, dried, are sold under the name of orangettes or Curaçoa oranges. The rootstock of the *Iris florentina* is also formed into peas, and used for keeping up the discharge from issues.

ISTHMIAN GAMES. The Isthmia were one of the four great national festivals of Greece, the others being the Olympia, Pythia, and Nemea. The Isthmia were celebrated under the presidency of the Corinthians, near Corinth, on the isthmus connecting Peloponnesus with the continent, at intervals of four years, corresponding with the recurrence of the other festivals above-mentioned, so that each year had its solemnity. The Isthmian games were first established in honour of Melicertes, the son of Ino (Paus., i. 44), but were reorganised by Theseus in honour of Poseidon, the presiding deity of the isthmus. The crowns bestowed on victors were of pine-leaves, or, later, wreaths of ivy. After the fall of Corinth the Isthmia were celebrated under the direction of the Sicyonians, until Corinth was re-built, when they were restored to the Corinthians, and continued to be celebrated till the establishment of Christianity. As all these games were similar in their object, contests, and ceremonies, it will be sufficient to refer for further details to the article on the principal of them, the Olympia. [OLYMPIAN GAMES.]

ITACONAMIC ACID ($C_{10}H_7NO_6$). A brown amorphous acid, formed by heating the itaconate of ammonia. Its salts are very instable. In like manner, by heating the itaconate of aniline *itaconanilic acid* ($C_{10}H_6(C_{12}H_5)NO_6$) or *phenyl-itaconamic acid* is obtained.

ITACONANILIDE ($C_{10}H_8(C_{12}H_5)_2N_2O_4$), *Phenyl-itaconamide.* An unimportant derivative from citric acid. [ANILIDES.]

ITACONANILIC ACID. [ITACONAMIC ACID.]

ITACONIC ACID ($C_{10}H_4O_6,2HO$). When citric or aconitic acid is distilled, two liquids are obtained in the receiver, the lighter of which mixes perfectly with water, whilst the heavier, which is oleaginous, combines with it slowly, and becomes a crystalline mass, to this a sufficient quantity of boiling water is to be added to dissolve the oleaginous liquid and the crystals formed, and the solution is to remain exposed to the air; after some days' spontaneous evaporation, crystals of itaconic acid are deposited, which are transparent and hard; these are to be purified by repeated crystallisations from water.

The properties of the itaconic acid thus prepared are :—It crystallises in rhombic tables or rhombic octohedrons. It has no smell, but possesses a very strong acid taste. It dissolves in 17 parts of water at 50°, and in 10 parts at 68°, and boiling water dissolves much more. It is soluble in alcohol and in ether; at 248° the crystals lose no weight. At 320° they melt, exhaling white irritating vapours, and volatilise without leaving any residue when the heat is continued. When subjected to distillation they decompose into anhydrous citraconic acid and water.

ITALIAN ARCHITECTURE. Instead of comprising buildings of every style and class to be met with in Italy, the term "Italian Architecture" is generally restricted to signify that generic style formed by the revival of the Roman orders, and the adaptation of them, and other features derived from works of the same age, to buildings of every kind, domestic as well as public. Without such limitation, the term would apply to buildings having nothing else in common than their locality, to the Ca d'Oro at Venice, no less than to the works of Palladio, and such modernised *Palladianism* as is exhibited in the design of the Teatro Fenice in the same city. Even with such limitation, the style presents so many varieties, both in regard to modes of treatment and taste of design, as to render it difficult to draw up a succinct account of it, if more be attempted than to explain the character of the orders and other leading external features, with their application, and the taste generally manifested in architectural design.

Italian architecture, thus restricted, arose in that remarkable era in Italian history when the Medici had gathered about them the learning, the poetry, and the art of the day, and the revived study of classic literature having imbued the educated classes with a deep reverence for everything classic, works of art, as well as literature, were anxiously moulded according to a Roman type. Instead, however, of proposing to themselves the remains of Roman antiquity as models to be freely followed in the same spirit, and modified as circumstances should require, Italian architects, in endeavouring to fix a new style founded upon the ancient orders, began by reducing the orders themselves to the strictest mechanical system possible; notwithstanding that for the Doric and Ionic they had no better guide than the few debased and insipid specimens which occur in Roman works, and the ambiguous explanations given in the text of Vitruvius, whom they looked up to as an infallible oracle.

Italian architecture then is, allowance being made for local varieties, a style founded upon the Roman antique as interpreted by the writings of Vitruvius, and reduced to a methodical system by Alberti, Vignola, and Palladio. It was, however, founded rather on the Coliseum, the baths, triumphal arches and other secular buildings of the Romans than on their temples. Its greatest triumphs were in the palaces and civic buildings, rather than in the churches, which it secularised, and as the phrase is, paganised. But the Italian architects in their revival of ancient art made no effort to *reproduce* the ancient buildings. Whilst they followed with pedantic strictness the teaching of Vitruvius and Alberti in reference to the orders separately considered, they allowed themselves the utmost licence in their application of them. Theirs was a new combination of parts, not a repetition of the whole; their principle was that of the adaptation of antique Roman forms and details to modern Italian buildings. These forms and details were often applied with little consideration or discrimination, but the general effect is nevertheless rich and imposing; and to Brunelleschi, Sansovino, and Palladio must be accorded the honour of having created a new and noble style of palatial and domestic architecture, rich in resources, and admitting of the combination of broad simplicity and dignity of treatment with freshness, elegance, and picturesqueness in the details. But it is essentially a civic style of architecture; the architecture of narrow streets and public places; an architecture whose buildings were to be seen close at hand and admired in detail, not like the ancient temples or mediæval cathedrals to awe the mind by grandeur of mass, as well as by the severe simplicity or multitudinous variety of subordinate parts.

The characteristic features of the Italian architecture of the 15th and 16th centuries, may be stated briefly, but cannot be so stated without leaving the statement exceedingly imperfect. As has been said, the characteristic which distinguished this from the architecture of the preceding centuries was the strict use of the Roman orders. But then these orders were employed rather as a decorative than a constructive feature; and applied without regard to classic precedent: and precedent being departed from in the primary instance, its neglect throughout followed as a necessary consequence. Thus different orders, or repetitions of the same order, being applied to the several stories of buildings whose fronts were pierced with windows, it became unavoidable to abandon all proportion of intercolumniation, and to space the columns according to the breadth of the piers and the apertures between them; which in turn left hardly any other alternative than to engage the columns themselves, that is, to attach either half or three-quarter columns to the walls, because insulated columns placed so wide apart from each other would have had an exceedingly poor and meagre effect. And where one order was placed above another, two straggling rows of low insulated pillars—for low they must be in comparison with the entire height of the building,—instead of at all ornamenting a building, would have incumbered it with what would have resembled stages of scaffolding.

For a somewhat similar reason, either pilasters were substituted for engaged columns, or the entablature was made to break over every column; for if, instead of being thus broken, the entablature were continued from column to column in each story, overhanging the face of the wall, it would produce an appearance of heaviness as well as weakness. One result of this practice of giving a separate order to each story is, that the columns become comparatively insignificant, both in proportion to the entire front and to the windows between them; more especially when the columns are further shortened by being placed on pedestals. In fact windows and doors are generally the predominant features in Italian composition, even where two series are comprised within one order, being generally more prominent in their cornices and pediments than the other projections. They are often decorated with smaller columns or pilasters, and Palladio has sometimes loaded them with recumbent figures on the raking cornices of their pediments. Sometimes, as in the upper order of the Procuratie Nuove, by Scamozzi, at Venice, the windows (decorated with a lesser order) are carried up to the height of the capitals. In instances like these the ornamental details may be in imitation of the members of an ancient order, but the antique character is gone. Even where the windows are kept more subordinate to the order itself, the effect of the order is frequently diminished by the addition of a heavy attic pierced with windows occupying its entire length, and surmounted in turn by a balustrade, having perhaps a formal row of statues on its pedestals, which viewed at a little distance assume the appearance of so many pinnacles on the summit of the building, whilst the balusters themselves in such cases suggest the idea of perforated battlements.

Another distinctive feature of Italian architecture is the frequent use of circular, and the introduction of broken, pediments over doors and windows. Cornices are sometimes made important features in the composition, but often they are rendered subordinate or altogether dispensed with, the balustrade being as we have seen made the crowning feature. In some of the richer examples sculpture is freely and very effectively introduced, though occasionally in a somewhat heterodox manner. Sculptured friezes and elegantly carved vases also contribute largely to the general effect.

But whilst much of the Italian architecture is *microstylar*, that is, has a separate small order to each floor, or horizontal division of a façade above the ground floor, much of it is *astylar*, that is, without columns; the windows and arches being the chief features of the composition, and either a full entablature or a bold, rich, and carefully proportioned cornicione crowning the entire mass. This large and simple mode of treatment was greatly affected by the Florentine and Roman architects of the period of the revival.

The example and influence of the revived Italian architecture was soon felt throughout Europe [RENAISSANCE ARCHITECTURE], and the Italian architects were everywhere looked up to and followed as the great masters of the profession, until the archæological researches of the last century, and particularly the examination of the architectural remains of ancient Greece, led to the desire for a closer imitation of classic, and especially of Greek forms: a fashion which has in its turn given way before the Gothic re-action.

In our own country the Italian style was first introduced, with any pretence to closeness of imitation, by Inigo Jones, and the Banqueting House, Whitehall, may be referred to as a favourable example both of the genius of the architect, and of the imitative Italian of the beginning of the 17th century. One of the latest English examples, prior to the eruption of the Greek furor, is Chambers's Somerset House; the court of the Strand portion of which is a good example of a late modified Italian style, where an order is placed on a decorated basement. In our own day the Italian style has been re-introduced with great though not unquestioned success. Sir Charles Barry, the first we believe to adopt it, has applied it with great ability in several of his more important domestic buildings. The Travellers' and the Reform club-houses in Pall Mall, both by him, will, with the adjoining Carlton Club (by Mr. Sidney Smirke), afford the reader a good idea of Italian architecture. All the three are copies, or adaptations, of celebrated Italian buildings: The astylar Travellers is an imitation of the Palazzo Pandolfini, at Florence; the Reform, a free adaptation of the Palazzo Farnese, at Rome; the microstylar Carlton, a direct copy from Sansovino's famous Library of St. Mark, Venice. Several of the other London club-houses are Italian in style, and more or less direct copies of existing Italian buildings.

ITCH, or as it is termed by nosologists, Scabies or Psora, is a disease of the skin, of which the most prominent symptom is a constant and intolerable itching. The eruption consists most commonly of minute vesicles filled with a clear watery fluid, and slightly elevated on small pimples; but its character is often obscured by a mixture of papulæ and pustules with the vesicles. Hence the disease has been divided into distinct species according to the predominance of each kind of eruption; but the distinction is artificial, and of no practical utility. The eruption occurs principally on the hands and wrists, and in those parts most exposed to friction, as the spaces between the fingers and the flexures of the joints. After a time it extends from these parts to the arms, legs, and trunk; but very rarely, if ever, appears on the face.

The itch is attended by no constitutional disorder, except in those severest forms in which the eruption consists chiefly of large pustules, surrounded by considerable inflammation of the adjacent skin. It never appears to arise spontaneously; but, where cleanliness is not strictly observed, it is easily communicated by contact. It is entirely due to the presence of a minute acarus under the skin known by the name of *Sarcoptes scabiei*. With the destruction of the insect the disease disappears. [ACARIDÆ, in NAT. HIST. DIV.]

A certain specific for the cure of the itch, which never gets well without treatment, is the local application of sulphur; all the parts on which the eruption is visible should be plentifully smeared with the *unguentum sulphuris* every night, or every night and morning, till the cure is perfected, which will require from three days to a fortnight, according to the severity and extent of the disease. The ointment must remain on the parts after each application, and occasional warm baths ought to be used during the treatment.

IVORY, the substance which composes the teeth or tusks of elephants, is extensively used in the arts for making or embellishing numberless small articles in almost universal use. The principal supplies of elephants' teeth to this country are derived from the west coast of Africa and from Ceylon. The remaining imports are chiefly from the coast of Barbary, the Cape of Good Hope, Madagascar, and Siam. The United States of America also send to this country some of the ivory which they import; and fossil ivory occasionally reaches England from Russia. The demand has much increased within the last few years, and the supply can scarcely keep up with it. A great quantity is now brought over by the Peninsular Company's steamers from Alexandria, sometimes as much as 20,000*l*. worth in one cargo. This portion of the trade consists chiefly of wild elephants' tusks which have been shed in the deserts of Arabia, and bought up by the Pacha of Egypt for sale to English buyers. The teeth and tusks of the elephant, hippopotamus, wild boar, and narwhal, all form ivory of various kinds; though the the tusk of the elephant is that which usually goes by the name. The fossil mammoth, often found in Siberia, was a kind of elephant; and the ivory of the tusks is very similar to that of the elephant of the present day. The Russians almost wholly make use of this kind of ivory. Some of the mammoth tusks are 10 feet long, solid to within 6 inches of the end, and weigh 168 lbs. Pianoforte makers occasionally veneer the white keys of those instruments with mammoth ivory.

For purposes of manufacture ivory is cut up by means of saws set in steel frames; the saws are from 15 to 30 inches long, from 1½ to 3 inches wide, and 1-50th of an inch thick; with the teeth sharp but coarse. From the peculiar curves and twists of each tusk, great art is required to cut up the ivory with least waste. Veneers are cut in a ratio of 30 to an inch thickness of ivory; and as the sawdust, together with the scraping from after processes, effect a waste of one-half, it often happens that 60 finished ivory veneers will be no more than an inch in aggregate thickness. The thin plates are used chiefly for miniatures and for memorandum-books. The Russians, some years ago, devised a mode of cutting wood veneers out of solid blocks, by slicing it spirally from the surface towards the centre, like unfolding a roll of cloth; and M. Pape, a pianoforte manufacturer at Paris, afterwards applied this method to the cutting of ivory veneers. He can produce sheets measuring 150 inches by 30; and with such sheets he has veneered the entire surface of pianofortes. Ivory forms a fine and delicate material for graduated scales in mathematical instruments; but it is liable to expand and contract, under alternations of weather, to an inconvenient degree—insomuch that the Tithe Commissioners have refused to permit the use of ivory scales in laying down the areas and boundaries of land.

Ivory, after being cut with the saw, is smoothed and polished by various means—such as very fine glass paper, or emery paper; whiting and water applied by wash leather; oil on a bit of rag; putty powder; Flanders brick, Trent sand, or powdered chalk, wetted, and applied with flannel or a brush; or scraping and then rubbing on soft wheels. The list wheels employed by ivory-workers consist of 10 to 20 circular pieces of woollen cloth, screwed tightly between two wooden discs of rather smaller diameter; the cloth forms a pliant edge projecting beyond the wood; such wheels when moistened with Trent sand, are used for polishing parasol handles and similar articles. The chief demand in England for ivory is for making knife-handles and combs.

Ivory is often engraved by the French artists. They first cover the surface with a ground of wax or composition; then etch the design in this ground; then bite it in by a dilute solution of nitrate of silver; then wash in distilled water, dry with blotting-paper, and expose for one hour to the sun's rays. When the ground has been removed by the action of essence of turpentine, the design presents itself as a series of brownish lines, which soon become nearly black. The design may be developed in other tints if, instead of nitrate of silver, there be used nitro-muriate of gold or platinum, or nitrate of copper. Sometimes the ivory itself is engraved, and the lines filled in with hard black varnish. Another mode of ornamenting ivory is to engrave a design on a copper plate, take an impression on paper, transfer this impression to the ivory, stop out the blank portions with guiacum varnish, submit the ivory to the action of dilute acid, and then melt or wash off the varnish; there will result a tinted engraving on the surface of the ivory.

Mr. Cheverton in 1850 patented a mode of making what he terms artificial ivory. It consists in giving an ivory-like surface to gypsum or alabaster. The ornaments or other articles made of this material are exposed for forty-eight hours to a temperature of 300° Fahr., by which the moisture is driven off. They are then immersed till saturated in olive oil or in white hard varnish; and after being steeped several times in warm water, they are polished with whiting or putty powder, by which they obtain an ivory-like surface. M. Franchi has devised a somewhat similar mode of imitating ivory by preparing a mixture of 32 parts plaster of Paris with 1 of Italian yellow ochre; the materials are reduced to powder, sifted, mixed, liquefied with water, cast in moulds, dried in the open air, baked in an oven, and soaked while hot for a quarter of an hour in a hot mixture of equal parts of spermaceti, white wax, and stearine; the cast is finally brushed while warm, and polished with a tuft of cotton wool when cold.

The curious substance called *vegetable ivory*, is the seed of a genus of plants named *Phytelephas*, from *phuton* and *elephas*, the Greek version of its English name. An account of it, and of its uses, will be found under PHYTELEPHAS, in NAT. HIST. DIV.

IVORY BLACK. [BONE BLACK.]

IXOLITE. A mineral hydrocarbon resembling *hartite*.

J

J, in the English language, has a sibilant sound, closely connected with that of the syllable *di* before a vowel. [ALPHABET.] It has a similar sound in the French tongue; but in German it is pronounced altogether as our *y* before a vowel. What its pronunciation was in Latin may admit of dispute, for although it is generally laid down that its power with the Romans was the same as with the Germans, there is reason for thinking that our own sound of the letter was not unknown to the ancient inhabitants of Italy. The name of Jupiter was undoubtedly written originally Diupiter, so Janus was at first Dianus, just as the goddess Diana was called by the rustics Jana. (See D and I.) The argument might be strengthened by comparing the Latin *jungo* with the Greek ζευγνυμι, Jupiter with Ζευ πατερ, &c., and also by referring to the modern Italian forms, *Giogo*, *giovare*, *giovenco*, *giovane*, &c. There is no absurdity in supposing that two pronunciations may have co-existed in the same country. As to the form of the letter *j*, it was originally identical with that of *i*, and the distinction between them is of recent date. Exactly in the same way, among the numerals used in medical prescriptions, it is the practice to write the last symbol for unity with a longer stroke, *vj vij*, *viij*.

In the Spanish language *j* represents a guttural, and is now used instead of *x*, which had the same power: thus Jeres rather than Xeres is the name of the town which gives its title to the wine called by us sherry. For the changes to which *j* is liable, see D, G, and I.

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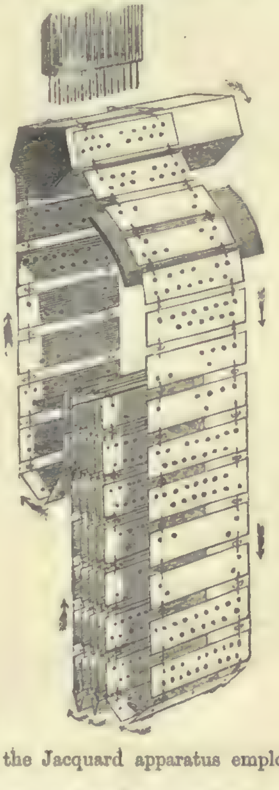

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has a separate small order to each floor, or horizontal division of a façade above the ground floor, much of it is *astylar*, that is, without columns; the windows and arches being the chief features of the composition, and either a full entablature or a bold, rich, and carefully proportioned cornicione crowning the entire mass. This large and simple mode of treatment was greatly affected by the Florentine and Roman architects of the period of the revival.

The example and influence of the revived Italian architecture was soon felt throughout Europe [RENAISSANCE ARCHITECTURE], and the Italian architects were everywhere looked up to and followed as the great masters of the profession, until the archæological researches of the last century, and particularly the examination of the architectural remains of ancient Greece, led to the desire for a closer imitation of classic, and especially of Greek forms: a fashion which has in its turn given way before the Gothic re-action.

In our own country the Italian style was first introduced, with any pretence to closeness of imitation, by Inigo Jones, and the Banqueting House, Whitehall, may be referred to as a favourable example both of the genius of the architect, and of the imitative Italian of the beginning of the 17th century. One of the latest English examples, prior to the eruption of the Greek furor, is Chambers's Somerset House; the court of the Strand portion of which is a good example of a late modified Italian style, where an order is placed on a decorated basement. In our own day the Italian style has been re-introduced with great though not unquestioned success. Sir Charles Barry, the first we believe to adopt it, has applied it with great ability in several of his more important domestic buildings. The Travellers' and the Reform club-houses in Pall Mall, both by him, will, with the adjoining Carlton Club (by Mr. Sidney Smirke), afford the reader a good idea of Italian architecture. All the three are copies, or adaptations, of celebrated Italian buildings: The astylar Travellers is an imitation of the Palazzo Pandolfini, at Florence; the Reform, a free adaptation of the Palazzo Farnese, at Rome; the microstylar Carlton, a direct copy from Sansovino's famous Library of St. Mark, Venice. Several of the other London club-houses are Italian in style, and more or less direct copies of existing Italian buildings.

ITCH, or as it is termed by nosologists, Scabies or Psora, is a disease of the skin, of which the most prominent symptom is a constant and intolerable itching. The eruption consists most commonly of minute vesicles filled with a clear watery fluid, and slightly elevated on small pimples; but its character is often obscured by a mixture of papulæ and pustules with the vesicles. Hence the disease has been divided into distinct species according to the predominance of each kind of eruption; but the distinction is artificial, and of no practical utility. The eruption occurs principally on the hands and wrists, and in those parts most exposed to friction, as the spaces between the fingers and the flexures of the joints. After a time it extends from these parts to the arms, legs, and trunk; but very rarely, if ever, appears on the face.

The itch is attended by no constitutional disorder, except in those severest forms in which the eruption consists chiefly of large pustules, surrounded by considerable inflammation of the adjacent skin. It never appears to arise spontaneously: but, where cleanliness is not strictly observed, it is easily communicated by contact. It is entirely due to the presence of a minute acarus under the skin known by the name of *Sarcoptes scabiei*. With the destruction of the insect the disease disappears. [ACARIDÆ, in NAT. HIST. DIV.]

A certain specific for the cure of the itch, which never gets well without treatment, is the local application of sulphur; all the parts on which the eruption is visible should be plentifully smeared with the *unguentum sulphuris* every night, or every night and morning, till the cure is perfected, which will require from three days to a fortnight, according to the severity and extent of the disease. The ointment must remain on the parts after each application, and occasional warm baths ought to be used during the treatment.

IVORY, the substance which composes the teeth or tusks of elephants, is extensively used in the arts for making or embellishing numberless small articles in almost universal use. The principal supplies of elephants' teeth to this country are derived from the west coast of Africa and from Ceylon. The remaining imports are chiefly from the coast of Barbary, the Cape of Good Hope, Madagascar, and Siam. The United States of America also send to this country some of the ivory which they import; and fossil ivory occasionally reaches England from Russia. The demand has much increased within the last few years, and the supply can scarcely keep up with it. A great quantity is now brought over by the Peninsular Company's steamers from Alexandria, sometimes as much as 20,000*l*. worth in one cargo. This portion of the trade consists chiefly of wild elephants' tusks which have been shed in the deserts of Arabia, and bought up by the Pacha of Egypt for sale to English buyers. The teeth and tusks of the elephant, hippopotamus, wild boar, and narwhal, all form ivory of various kinds; though the the tusk of the elephant is that which usually goes by the name. The fossil mammoth, often found in Siberia, was a kind of elephant; and the ivory of the tusks is very similar to that of the elephant of the present day. The Russians almost wholly make use of this kind of ivory. Some of the mammoth tusks are 10 feet long, solid to within 6 inches of the end, and weigh 168 lbs. Pianoforte makers occasionally veneer the white keys of those instruments with mammoth ivory.

For purposes of manufacture ivory is cut up by means of saws set in steel frames; the saws are from 15 to 30 inches long, from 1½ to 3 inches wide, and 1-50th of an inch thick; with the teeth sharp but coarse. From the peculiar curves and twists of each tusk, great art is required to cut up the ivory with least waste. Veneers are cut in a ratio of 30 to an inch thickness of ivory; and as the sawdust, together with the scraping from after processes, effect a waste of one-half, it often happens that 60 finished ivory veneers will be no more than an inch in aggregate thickness. The thin plates are used chiefly for miniatures and for memorandum-books. The Russians, some years ago, devised a mode of cutting wood veneers out of solid blocks, by slicing it spirally from the surface towards the centre, like unfolding a roll of cloth; and M. Pape, a pianoforte manufacturer at Paris, afterwards applied this method to the cutting of ivory veneers. He can produce sheets measuring 150 inches by 30; and with such sheets he has veneered the entire surface of pianofortes. Ivory forms a fine and delicate material for graduated scales in mathematical instruments; but it is liable to expand and contract, under alternations of weather, to an inconvenient degree—insomuch that the Tithe Commissioners have refused to permit the use of ivory scales in laying down the areas and boundaries of land.

Ivory, after being cut with the saw, is smoothed and polished by various means such as very fine glass paper, or emery paper; whiting and water applied by wash leather; oil on a bit of rag; putty powder; Flanders brick, Trent sand, or powdered chalk, wetted, and applied with flannel or a brush; or scraping and then rubbing on soft wheels. The list wheels employed by ivory-workers consist of 10 to 20 circular pieces of woollen cloth, screwed tightly between two wooden discs of rather smaller diameter; the cloth forms a pliant edge projecting beyond the wood; such wheels when moistened with Trent sand, are used for polishing parasol handles and similar articles. The chief demand in England for ivory is for making knife-handles and combs.

Ivory is often engraved by the French artists. They first cover the surface with a ground of wax or composition; then etch the design in this ground; then bite it in by a dilute solution of nitrate of silver; then wash in distilled water, dry with blotting-paper, and expose for one hour to the sun's rays. When the ground has been removed by the action of essence of turpentine, the design presents itself as a series of brownish lines, which soon become nearly black. The design may be developed in other tints if, instead of nitrate of silver, there be used nitro-muriate of gold or platinum, or nitrate of copper. Sometimes the ivory itself is engraved, and the lines filled in with hard black varnish. Another mode of ornamenting ivory is to engrave a design on a copper plate, take an impression on paper, transfer this impression to the ivory, stop out the blank portions with guiacum varnish, submit the ivory to the action of dilute acid, and then melt or wash off the varnish; there will result a tinted engraving on the surface of the ivory.

Mr. Cheverton in 1850 patented a mode of making what he terms artificial ivory. It consists in giving an ivory-like surface to gypsum or alabaster. The ornaments or other articles made of this material are exposed for forty-eight hours to a temperature of 300° Fahr., by which the moisture is driven off. They are then immersed till saturated in olive oil or in white hard varnish; and after being steeped several times in warm water, they are polished with whiting or putty powder, by which they obtain an ivory like surface. M. Franchi has devised a somewhat similar mode of imitating ivory by preparing a mixture of 32 parts plaster of Paris with 1 of Italian yellow ochre; the materials are reduced to powder, sifted, mixed, liquefied with water, cast in moulds, dried in the open air, baked in an oven, and soaked while hot for a quarter of an hour in a hot mixture of equal parts of spermaceti, white wax, and stearine; the cast is finally brushed while warm, and polished with a tuft of cotton wool when cold.

The curious substance called *vegetable ivory*, is the seed of a genus of plants named *Phytelephas*, from *phuton* and *elephas*, the Greek version of its English name. An account of it, and of its uses, will be found under PHYTELEPHAS, in NAT. HIST. DIV.

IVORY BLACK. [BONE BLACK.]

IXOLITE. A mineral hydrocarbon resembling *hartite*.

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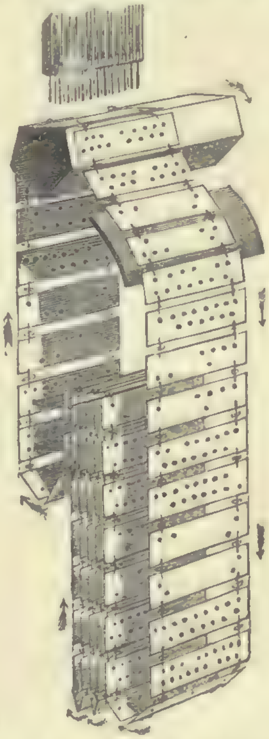

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Since Mr. Porter wrote, the extensions in the use of the Jacquard apparatus have been numerous and important; and many changes in the mode of working have been gradually introduced. Messrs Lamb of Kidderminster, in applying it to carpet weaving, have devised modes of ensuring a greater certainty of action, and a diminished liability to disarrangement. Mr. Mackenzie, a Spitalfields manufacturer, has substituted a number of compound needles for the revolving bars. Mr. Martin has devised a combination of perforated pattern papers, vertical needles, and presser bars, for selecting and acting upon a series of horizontal rods, by means of which the warp threads of the pattern are determined on. The old method involved a great wear and tear of cardboard, which induced some of the carpet manufacturers to substitute sheet iron. It has however since been found practicable to use a continuous strip of paper instead of a series of cards linked together. The stripe can be rapidly cut from a previously perforated sheet of paper; and any number of duplicates may be produced. It required a long time to prepare the cards for a new pattern, and this lessened the willingness to introduce novel designs, on account of the expense; but by lessening the cost and weight, through the introduction of paper great scope is given for the display of artistic variety. Messrs. Crossley, the eminent carpet manufacturers of Halifax, employ the Jacquard apparatus very largely in weaving the richer designs of carpet; it is also much used by the manufacturers of waistcoat fabrics at Huddersfield.

Some progress has been made towards the application of electricity, as a moving power, to the Jacquard apparatus. If the attempts prove successful, they will be noticed in WEAVING.

JAGANATH. [JUGGERNAUTH.]

JAINAS, a religious sect of the Hindus. The name is derived from the Sanskrit *jina*, "victorious," which is the generic name of the deified saints of this sect.

The Jainas are very numerous in the southern and western provinces of Hindustan; they are principally engaged in commerce, and from their wealth and influence form a very important division of the population of the country. The history and opinions of this sect are also interesting from their striking similarity to the chief peculiarities of the religion of Buddha. The earliest information concerning this sect was given in the 9th vol. of the 'Asiatic Researches,' in an 'Account of the Jains, collected from a priest of this sect, at Mudgeri, translated for Major Mackenzie;' in 'Particulars of the Jains,' by Dr. Buchanan: and in 'Observations of the sect of Jains,' by Colebrooke. Several particulars concerning them are also given in Buchanan's 'Journey from Madras through Mysore,' &c.; Wilks's 'Historical Sketch of the South of India;' in the work of the Abbé du Bois; and in Ward's 'View of the History, Literature, and Religion of the Hindus.' Information still more important is given in the 1st volume of the 'Transactions of the Royal Asiatic Society,' by Colebrooke, 'On the Philosophy of the Hindus;' by Major Delamain, 'On the Srâwaks, or Jains;' by Colebrooke, Dr. Hamilton, and Col. Franklin, 'On Inscriptions in Jain Temples in Behar;' by Dr. Hamilton, 'On the Srâwaks, or Jains;' and also in the 2nd volume of the Transactions, by Major Todd, 'On the Religious Establishments in Mewar.' But the most complete account of this sect is given by Prof. Wilson, in his 'Sketch of the Religious Sects of the Hindus.' ('As. Res.,' vol xvii.)

A view of the literature of the Jainas is given by Wilson in his 'Descriptive Catalogue of the MSS., &c., of Col. Mackenzie,' vol. ii., pp. 144–162. The Jainas have their own Purânas and other religious works, which are principally devoted to the history of the Tôrthankaras, or deified teachers of the sect. The chief Purânas are supposed to have been written by Jina Sena Achârya, who was probably the spiritual preceptor of Amoghaversha, king of Kânchi, at the end of the 9th century of the Christian era. They have also their own works on astronomy, astrology, medicine, the mathematical sciences, and the form and disposition of the universe, of which a list is given in Wilson's 'Descriptive Catalogue.' "But the list there given is very far from including the whole of Jain literature, or even a considerable proportion. The books there alluded to are in fact confined to Southern India, and are written in Sanskrit or the dialects of the peninsula; but every province of Hindustan can produce Jain compositions, either in Sanskrit or its vernacular idiom; whilst many of the books, and especially those that may be regarded as their Scriptural authorities, are written in the Prakrit or Magadhi, a dialect which, with the Jains as well as the Buddhas, is considered to be the appropriate vehicle of their sacred literature." (Wilson, 'As. Res.,' vol. xvii., pp. 242-3.) The Jainas are also said to have a number of works entitled Siddhantas and Agamas, which are to them what the Vedas are to the Brahmanical Hindus.

The Jainas are considered by the Brahmans to form no part of the Hindu Church. The principal points of difference between them and the Brahmanical Hindus are—1st, a denial of the divine origin of the Vedas; 2ndly, the worship of certain holy mortals who have acquired by self-mortification and penance a power which renders them superior to the gods; and 3rdly, extreme tenderness for animal life. These doctrines and customs are essentially the same as those of the Buddhists. The Jainas do not entirely reject the gods of the Hindu mythology; but they consider them greatly inferior to the Jinas, who are the object of their religious adoration. The statues of all or part of these are in all their temples, sculptured in black or white marble. They are distinguished from each other in colour and stature: two are represented as red, two as white, two as blue, two as black, and the rest as of a golden hue or yellowish-brown. Of these Jinas the most celebrated are Pârsvanâtha and Mahâvira, who alone can be regarded as having any historical existence.

The origin of this sect has been a subject of much dispute. Some have endeavoured to prove that Buddhism and Jinism are more ancient than the Brahmanical religion; but several arguments have already been brought forward in another part of this work which render this hypothesis exceedingly improbable. [BUDDHISM.] It has, on the contrary, been maintained with greater probability, from the absence of all allusion to Jinism in the ancient Brahmanical and Buddhistic works, and from the comparatively late date of all inscriptions and monuments relating to the Jainas which have yet been discovered, none being earlier than the 9th century, that the sect of the Jainas did not become of any importance till the 8th or 9th century of the Christian era. The striking similarity between the Buddhists and Jainas renders it probable that they had the same origin, and that Jinism is merely another form of Buddhism, accommodated to the prejudices of the Brahmanical Hindus. In the southern provinces of Hindustan, where the Jainas are the most numerous, the distinction of castes is preserved among this sect; but it appears probable, from many circumstances, that originally they had no distinction of caste; and even in the present day, in the upper provinces, the Jainas all profess to be of one caste, namely, the Vaisyas, which is equivalent to their being of no caste at all. The Jainas also allow Brahmans to officiate as the priests of their temples. The period in which we have supposed Jinism to have first risen into importance coresponds with the time in which the Buddhists were finally expelled from Hindustan. (Wilson's 'Sanskrit Dictionary,' 1st edit., preface, pp. xv.-xx.) It therefore appears probable that those Buddhists who were allowed to remain adopted the opinions and practices of Jinism, which may previously have existed as an insignificant division of the Buddhistic faith. In the 11th and 12th centuries the religion of the Jainas appears to have been more widely diffused than at any other period. Many princes in the southern part of the peninsula embraced this faith; but it gradually lost much of its power and influence, in consequence of the rapid progress of the Vaishnavas and Saivas.

The Jainas were anciently called Arhatas, and are divided into two sects, of which the former is called Vivasanas, Muktavasanas, Mucktâmbaras, or Digambaras, in reference to the nakedness of this order; and the latter Swetâmbaras, "clad in white," because the teachers of this sect wear white garments. The former are the more ancient. In the early philosophical writings of the Hindus, in which the Jainas are mentioned, they are almost always called Digambaras, or Nagnas, "naked." The term Jaina rarely occurs, and that of Swetâmbara still more rarely. These two sects, though differing from each other in very few points, oppose one another with the bitterest animosity.

The Jainas are also divided into Yatis and Srâvakas, clerical and lay, the former of whom subsist upon the alms of the latter. The religious ritual of the Jainas is very simple. The Yatis dispense with acts of devotion at their pleasure; and the Srâvakas are only bound to visit a temple daily, where some of the images of the Jinas are erected, and make a trifling offering of fruit and flowers, accompanied by a short prayer. The Jaina temples are generally superior in size and beauty to those which belong to the Brahmanical religion. [INDIA, ARCHITECTURE OF.] Bishop Heber has given an account of his visit to one of these temples, from which strangers are usually excluded with jealous precautions. "The priest led us," he says, "into a succession of six small rooms, with an altar at the end of each, not unlike those in Roman Catholic chapels, with a little niche on one side, resembling what in such churches they call the *piscina*. In the centre of each room was a large tray with rice and ghee strongly perfumed, apparently as an offering, and men seated on their heels on the floor, with their hands folded as in prayer or religious contemplation. Over each of the altars was an altar-piece, a large bas-relief in marble, containing, the first five, the last in succession twenty-five figures, all of men sitting cross-legged, one considerably larger than the rest, and represented as a negro. He, the priest said, was their god; the rest were the different bodies he had assumed at different epochs, when he had become incarnate to instruct mankind. The doctrines he had delivered on these occasions make up their theology; and the progress which any one has made in these mysteries entitles him to worship in one or more of the successive apartments which were shown us." ('Journal,' i., p. 292.)

The moral code of the Jainas is expressed in five *Mahâvratas*, or "great duties:" 1st, refraining from injury to life; 2nd, truth; 3rd, honesty; 4th, chastity; 5th, freedom from worldly desires. There are also four *Dhermas*, or "merits:" liberality, gentleness, piety, and penance.

JALAP is obtained from several plants of the tribe of the *Convolvulaceæ*. The best is procured from the *Exogonium purga* (Bentham), called also *Ipomæa purga*. It is a native of Mexico, growing high up in the mountains. Jalap is chiefly shipped from Vera Cruz, and takes its name from the town of Xalapa, or Jalapa, in the interior. It is best when collected in March or April, before the young shoots have begun to be developed. The large root, which often weighs 50 pounds, is divided into portions, which are hung in nets over a fire, and dried in ten or twelve days. It occurs in commerce in irregular round or pear-shaped masses, which, when good, are dry, hard, with a brown shining fracture, resinous, not light, somewhat tough. It is often adulterated with portions of the root of white bryony, which, however, are white, or when old, gray, not heavy, very brittle, fracture not resinous, spongy, without smell, but with very bitter taste. Dried pears are also often substituted for it; but they may be detected by being laid open, when the core will be seen, containing the seeds. Analysed by Cadet de Gassicourt, 100 parts of the dry root yielded resin 10, gummy extractive 44, woody fibre 29, starch, albumen, salts of lime, and potass, &c. According to the more recent analysis of Guibourt, some specimens yield 17 per cent. of resin: false rose-scented jalap as little as 3 per cent. Jalapina, or rhodeoretia, is an alkaloid discovered by Mr. Hume. It is a transparent, colourless, odourless, tasteless resin. These qualities recommend it to children, for whose complaints it is extremely well suited.

Ipomœa turbethum yields the jalap of the East Indies. But there is scarcely a single species of this genus that does not yield more or less of a purgative principle, and generally called jalap. These, and nearly all substitutes for the genuine jalap, are enumerated by Dr. Theodor Martius, in his 'Pharmakognosie des Pflanzenreiches,' Erlangen, 1832. The so-called *twigs* (stipites) of jalap, are really the roots or tubers of *Ipomœa orizabensis* (Ledanois), *Convolvulus orizabensis* of Pelletan. *Ipomœa leatatoides*, Benth., 'Bot. Register,' January, 1841. It yields the inferior, light, or male jalap, and contains an alkaloid called Pararhodeoretia.

Its excellence depends upon the quantity of resin; a white jalap (from *C. Mechoacanna*) is sometimes met with, which contains only 2 per cent of resin; its dose must be five or six times as great as that of the genuine jalap.

Jalap is ranged with the drastic purgatives, and where one of a resinous kind is desired, is that usually selected. Its action is generally certain, and when in combination with other substances, mild and speedy. It does not seem greatly to influence the nerves of the abdomen, but rather the vascular system of the pelvis and lymphatic system of the intestines. It is given in obstruction of the liver, vena-porta, and diseases connected with these organs, such as hypochondriasis, melancholia, jaundice, dropsy, and intermittent fevers; but at the commencement of common fevers, along with calomel, it is of great utility; also in the inflammatory or turgescent stage of hydrocephalus, and in the treatment of worm cases.

JALAPIC ACID ($C_{66}H_{59}O_{35}$?). An uncrystallisable acid produced by the metamorphosis of jalapin under the influence of alkalies. It is homologous with convolvulic acid.

JALAPIN. [CONVOLVULIN.]

JALAPINOL ($C_{32}H_{31}O_7$?). A crystalline substance insoluble in cold water, produced by the action of boiling dilute acids upon jalapin and jalapic acid. Treated with caustic alkalies it forms *jalapinolic acid* ($C_{32}H_{30}O_8$?)

JALAPINOLIC ACID. [JALAPINOL.]

JALLOFFS, or YALLOFFS, a negro tribe who occupy a considerable tract of country between the rivers Senegal and Gambia. They are considered as the finest race of negroes in this part of Africa; they are tall and well made, their features are regular, and their physiognomy open. Though bordering on the Foolahs and Mandingos, they differ from both, not only in language, but in features. The noses of the Jalloffs are not so much depressed nor the lips so protuberant as among the generality of Africans, but their skin is of the deepest black. They are chiefly employed in agriculture, and have made some progress in the useful arts, especially in the manufacture of cotton cloth, which they make better than any of the neighbouring tribes. They are divided into several independent states, or kingdoms, which are frequently at war either with their neighbours or with each other.

JAMAICINE is found with *Surinamine* in the *Geoffrœa inermis* and *G. Surinamensis*. They are crystallisable alkaloids, capable of forming salts with the acids, which are precipitated by tannin and corrosive sublimate.

JANIZARIES is the name of a Turkish militia once formidable but now extinct. The origin of this body dates from the reign of Amurath, or Murad I., who, after having overrun Albania, Bosnia, Servia, and Bulgaria, claimed the fifth part of the captives, from among whom he chose the young and able-bodied, and had them educated in the Mohammedan religion, and for the military profession. These recruits, being duly disciplined, were formed into a distinct body of infantry, divided into ortas, or battalions, and they were consecrated and blessed by a celebrated dervish called Hadji Bektash, who gave them the name of Yeni Cheri, or "New Soldiers." They soon became the terror of the enemies of the Ottomans: being completely weaned from their friends and homes, they were enthusiastically devoted to their sultan as their common father; and a strict discipline, regular pay, and constant service gave them habits of order and obedience far superior to the irregular bodies which formed at the time the armies of the princes of Christendom. After the death of Solyman the Magnificent, and the general though gradual decay of the Ottoman warlike spirit, when the sultans no longer took the field in person, the Janizary body was no longer recruited exclusively from choice and young captives, but by enrolments of Osmanlees, who being born and bred in the faith of Islam, had not the zeal of proselytes, and were besides connected by ties of consanguinity and friendship with the body of the people around them, and not exclusively devoted to the will of the sultan. In 1680 Mohammed IV. abolished the law by which the Christian rayahs, or subjects of the Porte, were obliged to give a portion of their children to the sultan to be educated in the Mohammedan faith and enrolled into the militia. By the original laws of their body the Janizaries could not marry, but by degrees the prohibition was evaded, and at last totally disregarded. Their children's names were then inscribed on the rolls of their respective ortas; and their relations and friends, men often unfit for any warlike service, obtained a similar honour, which gave them certain privileges and protection from the capricious oppression of their rulers. In this manner a crowd of menials, low artisans, and vagabonds, came to be included in the body of Janizaries; even rayahs and Jews purchased for money the same privilege; but all this motley crew lived out of the barracks, where only a few in time of peace were present at the appointed hours for receiving their soups or rations. Military exercises were abandoned; the Janizaries merely furnished a few guards and patroles for the city, many of them being only armed with sticks; and they never assembled as a body except on pay-day, when they defiled two by two before their nazirs, or inspectors. Still they were formidable to the government from their numbers, which were scattered all over the empire, and their influence and connections with the mob of the capital. They repeatedly mutinied against the sultans, and obliged them to change their ministers, or even deposed them. In our own days they dethroned Selim; and in the beginning of the reign of the late Sultan Mahmood they broke out into a dreadful insurrection which lasted three days, and in which the Vizir Mustapha Bairactar lost his life. In both instances they were impelled by their hatred of the Nizam Djedid, or new troops, disciplined after the European fashion. At last Mahmood resolved to put down the Janizaries; and having for several years matured his plan with the advice of his favourite Halet Effendi, and gained over their aga and others of their principal officers, he issued an order that every orta or division should furnish 150 men to be drilled according to the European tactics. This, as he had foreseen, led to a revolt; the Janizaries assembled in the square of the Etmaidan, reversed their soup-kettles according to their custom in such cases, and, invoking the name of their tutelary saint Hadji Bektash, they began by attacking and plundering the houses of their enemies. But the body of topjis, or cannoniers, the bostandjis, or guards of the seraglio, and the galiondjis, or marines, were prepared; the sultan, mufti, and the ulemas, assembled in the mosque of Achmet, pronounced a curse and a sentence of eternal dissolution on the body of the Janizaries; the sandjak shereef, or sacred standard, was unfurled, and a general attack on the Janizaries began, who, cooped up in the narrow streets, were mowed down by grape-shot, and the rest were despatched by the muskets and the yataghans of their enemies, or burned in their barracks. About 25,000 Janizaries are said to have been engaged in the actual revolt, and most of them perished: the others concealed themselves or were exiled into Asia. This carnage took place in June, 1825, and from that time the Janizaries as a body have ceased to exist. Macfarlane, in his 'Constantinople in 1828,' gives a vivid account of that catastrophe.

JANSENISTS, a sect which appeared in the Roman Catholic church about the middle of the 17th century. They professed not to attack the dogmas but only the discipline of that church, which however stigmatised them as heretical in some of their tenets. They took their name from Janssen, or Jansenius, bishop of Ypres in the Netherlands, who published a book entitled 'Augustinus,' in which he supported, by means of passages from the writings of St. Augustine, certain principles concerning the nature and efficacy of divine grace which appear to partake greatly of Calvin's doctrine of predestination. This question of grace and predestination had already been discussed in the church at various times, and had proved a stumbling-block to many theologians. Michael Baius, professor at Louvain, had been condemned in 1567 by a papal bull, and obliged to disown seventy-six propositions taken from his writings, chiefly concerning that abstruse subject. Jansenius however died quietly at Ypres in 1638, and it was not till several years after his death that some Jesuit theologians, on examining his book, discovered in it the following five propositions, which they denounced as heretical:—1. That there are certain commandments of God which even righteous men, however desirous, find it impossible to obey, because they have not yet received a sufficient measure of grace to render obedience possible. 2. That nobody can resist the influence of inward grace. 3. In our fallen state of nature it is not required, in order that we be accounted responsible beings, that we should be free from the internal necessity of acting, provided we are free from external constraint. 4. The Semi-Pelagians were heretical in maintaining that the human will has the choice of resisting or obeying the internal grace. 5. That to maintain that Christ died for all men, and not solely for those who are predestinated, is Semi-Pelagianism.

After much controversy, these five propositions were condemned by a bull of Pope Innocent X., in the year 1653, as impious and blasphemous, and the bull was received by the French prelates, and promulgated throughout France with the king's consent. Several learned men, who disliked the Jesuits and their latitudinarian system of ethics, wrote not to defend the five propositions, but to prove that these propositions did not exist in the book of Jansenius, at least not in the sense for which they were condemned. The Jesuits again appealed to the pope, and a curious question arose for the pope, which was, to determine the exact meaning of an author who was dead. Alexander VII. however, by a new bull, in 1656, again condemned Jansenius's book as containing the five propositions in the sense ascribed to them by the former bull. Arnauld and other learned men of Port-Royal persisted in denying this assumed meaning; and thus they, and all those who thought like them, received the appellation of Jansenists. A formulary was now drawn out conformable to the papal bull, which all ecclesiastical persons in France were required to sign, on pain of being suspended from their functions and offices. A great many refused, and this occasioned a schism in the French church, which lasted many years. Arnauld, Pascal, Nicole, and other reputed Jansenists attacked vehemently the corruption, discipline, and morality of the church, and the Jesuits as supporters of that relaxation. [PASCAL, in BIOG. DIV.] They also inculcated the necessity of mental rather than outward or ceremonial devotion; they promoted the knowledge of the Scriptures among the people, and they encouraged general education by numerous good works which came from the press of Port-Royal. Meantime the controversy with Rome continued, although Clement IX., in 1668, entered into a sort of compromise with the French non-subscribing clergy, and Innocent XI. behaved with still greater moderation towards them. But Father Quesnel's 'Moral Observations on the New Testament,' published in 1698, added fuel to the flame. Quesnel, being now considered at the head of the Jansenist party, was driven into exile; Louis XIV., urged by his Jesuit confessor, suppressed the monastery of Port-Royal in 1709; and Pope Clement XI., in 1713, fulminated the bull 'Unigenitus' against 101 propositions of Father Quesnel's work. [CLEMENT XI. in BIOG. DIV.] A fresh contention now arose; a great part of the French clergy, many of whom were not Jansenists, including Cardinal de Noailles, appealed from the bull of the pope to a general council. The Regent d'Orléans however insisted on unconditional submission to the bull, and the recusants, or "appellants," were persecuted and driven into exile. This persecution made many fanatics, and Jansenism became a name for a set of visionaries and impostors. A certain Abbé Paris, who had been one of the appellants, and had died in 1727, was said to perform miracles from his tomb. For an investigation of these pretended miracles, see Bishop Douglas's 'Criterion, or Miracles Examined.' Next came a set of men called Convulsionnaires, who were seized with spasms and ecstasies; and others who were styled Flagellants, who whipped themselves in honour of the Saint Abbé Paris. This frenzy lasted for years, and the government by harsh measures only increased it; in fact it became mixed up with political discontent, and the parliament of Paris took the part of the appellants. At last the paroxysm subsided, having had the effect of discrediting the name of Jansenism, which, as a sect, never afterwards revived, though its opinions are still held by many. As the original Jansenists maintained the absolute independence of the civil power on ecclesiastical authority, and as even in ecclesiastical matters they were not favourable to the supremacy of the Roman see, their principles had the effect of inducing many of the French clergy to take the oath to the constitution of 1791; these were called "prêtres insermentés," and were considered as schismatics by the see of Rome. The Jansenist principles extended to Italy, especially to Tuscany, where bishop Ricci and his partisans also effected a temporary schism.

JANUARY, the first month in our present Calendar, was also the first month in the Roman Calendar. It was not the first month of the year in this country till 1752, when the legislature, by an act passed in the preceding year, altered the mode of reckoning time from the Julian to the Gregorian style. At this time it was directed that the legal year, which then commenced in some parts of this country in March, and in others in January, should universally be deemed to begin on the first of January. January derives its name from Janus. Macrobius expressly says it was dedicated to him because from its situation, it might be considered to be retrospective to the past, and prospective to the opening year. It consists of thirty-one days, though originally of only thirty days. The Anglo-Saxons called January *Wolf-monath*.

JANUS, one of the most ancient and highest of the Roman deities. In mythological history, Janus is the earliest of the Italian kings, and reigned in Latium, being contemporary with Saturn. He was succeeded by Picus and Faunus, who as well as himself, were worshipped by the Etruscans and Romans. Janus, by some accounts, was the son of the sun, and his attributes appear to connect him with sun-worship. He is the porter of heaven: he opens the year, the first month being named after him; he presides over the seasons, whence he is sometimes represented with four heads (Janus Quadrifrons), and his temples in that capacity were built with four equal sides, but only one entrance. He presides over production. He is the keeper of earth, sea, and sky; the guardian deity of gates, on which account he is commonly represented with two faces, because every door looks two ways; and thus he, the heavenly porter, can watch the east and west at once without turning. (Ovid, 'Fast.,' i. 140.) He usually carries a key in his left hand and a staff in the other. (Ib., 99.) His temples at Rome were numerous. In war time the gates of the principal one, that of Janus Quirinus, were always open; in peace they were closed to retain the wars within (Ib., 124); but they were shut once only between the reign of Numa and that of Augustus. In reference to this attribute he has the epithets of Clusius and Patuleius, the shutter and opener. All his attributes, numerous and complicated as they are, appear to have reference to this notion of opening and shutting, and are explained, by those who see in Janus a modification of the sun, in reference to the phenomena of day and night, and the pervading vivifying influence of the solar rays; though, as has been implied, the ancients also connected his name with *janua*, a door. As to the probable origin of the word Janus, see the articles ARTEMIS, and the letter J.

JAPANNING, is the art of producing a highly varnished surface on wood, metal, or other hard substance, sometimes of one colour only, but more commonly figured and ornamented. The process has received its name from that of the islands of Japan, whence articles so varnished were first brought to Europe; though the manufacture is also extensively practised by the Chinese, Siamese, Birmese, and other nations of the extreme east of Asia, among whom it was suggested most probably by the possession of a tree, which affords with little preparation a beautiful varnish, exceedingly well adapted for the purpose, and which hardens better than those prepared in Europe.

The appearance of japanned work is as various as the taste and fancy of the artists employed in it. Sometimes it is a plain black or red, with a gilded or painted border; or it is an imitation of marble, of fine grained or rare wood, or of tortoiseshell; sometimes a drawing, in which high finish, brilliant colour, and showy patterns are more sought than good design; and occasionally fine copperplate engravings are applied to a japanned surface. In all cases the work is highly polished and varnished. Japanning is applied to ladies' work-boxes and work-tables, toilet-boxes, cabinets, tea-caddies, fire-screens, tea-trays, bread-baskets, snuffers and trays, candlesticks, and a variety of other articles. A good deal of common wood-painting is also called japanning; but this differs from the more ordinary painter's work in little else than in using turpentine instead of oil to mix the colours with. Bedsteads, dressing-tables, wash-hand-stands, bed-room chairs, and similar articles of furniture are painted in this way.

Three processes are usually required in japanning; laying the ground, painting, and finishing. In addition to these processes, whenever the matter to be japanned is not sufficiently smooth to receive the varnish, or when it is too soft or coarse, it is sometimes prepared or primed before any of the proper japanning processes are applied. The preparatory mixture or priming is composed of size and chalk; it is put on with a brush like paint, and when perfectly dry it is brought to an even surface by rubbing with rush, and is then smoothed by a wet rag. The best japanners, however, disapprove of the use of priming, because its brittleness is very detrimental to the firmness of the varnishes laid over it; they use no substances which are of themselves unfit for receiving a varnish, or which they are unable to bring to a sufficiently smooth surface. For wood hard and fine enough to receive a varnish without priming, and for metals, paper, and leather, the only preparation necessary is a coat or two of varnish. In all these processes it is a rule to allow a day or two to intervene after every operation, that the work may be thoroughly dry.

When the work has been prepared, the ground is laid on; this is either all of one colour, or marbled, or done in imitation of tortoiseshell. The grounds are the ordinary pigments mixed with varnish, laid on smoothly with a brush: when thoroughly dry they are varnished, and afterwards polished by rubbing with a rag and tripoli or rotten stone; and, if the ground be white, with putty or starch and oil. The varnish used is either copal, seed lac, or made of the gums animi and mastic. The mode of laying the grounds varies greatly. That which is now generally followed is to lay on one or two thick coats of colour mixed with varnish, then to varnish three or four times, and afterwards to dry the work thoroughly in a stove. The colours are flake-white or white-lead, Prussian-blue, vermilion, Indian-red, king's-yellow, verdigris, and lamp-black; intermediate tints are made by mixtures of these; and an imitation of tortoiseshell is produced by vermilion and a varnish of linseed-oil and umber. When a particularly gorgeous appearance is desired, the ground may be laid entirely in gold. This is produced by going over the work with japanner's gold size, which, when dry enough to bear touching with the finger, but still soft and clammy, is covered with gold-dust, applied on a piece of soft wash-leather. Any other metallic dust may be laid on in the same way. Many receipts are given for preparing the japanner's gold size, but nearly all agree in making linseed-oil and gum animi the basis of the composition. A curious and very striking mode of laying the ground, called the *dip*, was formerly much practised. It was done by dropping small quantities of coloured varnish in a trough of water, over the surface of which it immediately spread in curious and often beautiful ramifications; into these the article was dipped; the colour was thus transferred to the work, and when dried was varnished and polished in the usual manner.

The work when thoroughly dry will now be ready for painting. Showiness and brilliancy are chiefly sought for in japanning, and bright colours with gold and bronze dust are largely employed. The colours are tempered with oil or varnish, and the metallic powders laid on with gold size. Copper-plate engravings or wood-cuts may also be executed in japan work. In this process the engraving is first printed off upon fine paper which has been previously prepared by a thick coat of isinglass or gum water. When the print is perfectly dry, it is applied with its face downwards upon the japan ground covered with a thin coat of copal varnish; the paper is then moistened on the back with a sponge dipped in warm water, which in a few minutes dissolves the isinglass or gum, and the paper which is thus loosened is gently taken away, leaving the impression on the work. Indian ink or other drawings upon paper may be transferred to the japanned ground in the same way. A more expeditious and very effectual mode of transferring an engraving is to print upon a smooth thick layer of a composition of glue, treacle, and whiting, which will receive an impression as perfectly as a sheet of paper: the composition, which is elastic and very flexible, may be immediately laid down upon the japanned surface, which will thus receive nearly as good an impression as if it could have been itself applied to the engraving.

In whatever manner the work has been painted or printed, or if all addition to the plain colour of the ground has been dispensed with, nothing now remains but the finishing. This is a very simple process. The workman chooses one of the before-named varnishes, and passes it over the work with a brush several times, until he judges the coating thick enough to bear the polish. It is an important precaution not to begin the varnishing until the preceding work is thoroughly dry, and to dry perfectly each coat before laying on a succeeding one. A hot stove is used in the best establishments to aid in drying the work. When thick enough, the varnish is polished by rubbing it with a rag dipped in finely-powdered tripoli or rotten-stone; towards the end of the operation a little oil is also applied to the rag, and the work is completed by rubbing with oil alone, to clear off the powder or any other impurity.

A peculiar species of japan-work is described under BURMESE WARE.

Japanning, as understood in the Birmingham and Wolverhampton district, is chiefly applied to the coating of sheet iron-trays, saucepans, and other articles, with black varnish or japan. It is carried on to an immense extent, and is largely executed by women and children. A more delicate variety of the art, also centered in Birmingham, will be found noticed under PAPIER MACHÉ.

JAPONIC ACID. [TANNIC ACIDS.]

JASHER, BOOK OF (סֵפֶר הַיָּשָׁר), or 'the book of the upright,' is twice referred to in the Old Testament as a work of authority. (Josh. x. 13; 2 Sam. i. 18.) Many conjectures have been formed concerning the author and contents of this book; but we have no means of arriving at any satisfactory determination on the subject, since the work appears to have been lost before the time of the Babylonish captivity. Some critics have imagined it to be the same work as the book of Judges, which is evidently incorrect from the quotation in the book of Samuel; St. Jerome and some Jewish authors that it was the book of Genesis; others, as Bishop Lowth and Gesenius, have maintained that it was a collection of national songs.

In the year 1751, a printer of the name of Ilive published a pretended translation of the book of Jasher, which was said to have been translated from the original Hebrew by Alcuin of Britain. This work was republished at Bristol in 1829. An interesting account, and an elaborate exposure of this literary forgery is given in Horne's 'Introduction to the Scriptures.' There are also two Rabbinical books of Jasher; one is a 'Treatise on the Jewish Laws,' written by Rabbi Ilam in the 13th century, and printed at Cracow in 1617; the other, pretends to be an explanation of the Pentateuch and Joshua, of which it is so much a mere repetition as to excite suspicion of its genuineness. The original, it is stated, was found at the time of the destruction of the Temple by Titus; it was preserved at Seville, and was printed in Hebrew at Venice in 1613. It has since been translated, and published by Mr. Noak, in New York; and the translator maintains that *this* is the book referred to in Joshua and in Samuel. Dr. S. P. Tregelles, in his edition of Horne's 'Introduction to the Scriptures,' (1856), says, "in character it ranks below most apocryphal books and similar forgeries."

Dr. W. J. Donaldson published in 1855 a book entitled 'Jashar Fragmenta Archetypa Carminum Hebraicorum in Masorethico Veteris Testamenti textu passim tessellata. Collegit, ordinavit, restituit, in unum corpus redegit, Latine exhibuit, Commentario instruxit.' In this work he endeavours to prove that the books of the Old Testament were none of them written before the time of Solomon, and then only as fragments, which he thinks formed the book of Jasher, or of the Upright; and that these fragments were subsequently worked up into the shape of the existing books, at least as far as the Psalms. This theory he supports by selecting certain passages, which he styles "the very marrow of divine truth," and considers them as the genuine fragments referred to in the passages in Joshua and in Samuel. It is scarcely necessary to give references to the passages so selected, but the work was printed at Berlin in Hebrew and Latin. To this, in 1855, the Rev. J. J. S. Perowne published a reply—'Remarks on Dr. Donaldson's Book, entitled Jashar;' in which he points out the unsatisfactory base of such a theory, founded on an arbitrary selection of passages "culled by editorial skill out of the midst of works already existing as a whole, published as a whole, and bearing internal evidences of order and unity of design." They extend from Genesis i., of which two verses are selected, to the dedication of the temple, Psalm lxviii.

JASON. [ARGONAUTS.]

JAUNDICE (from *jaune*, yellow) is the name given to those diseases in which the excretion of the bile being prevented, it is retained in the blood, or re-absorbed, and being diffused throughout the system, gives a yellow colour to the skin, and all the other tissues and secretions.

The name is however very indefinite, because the cases in which the separation of the bile is prevented are various. Everything, for example, which obstructs the main trunk of the bile-ducts, as gallstones [CALCULUS, BILIARY], or other foreign bodies filling its canal, certain morbid alterations of the liver or duodenum, or of the duct itself, tumours and enlargements of adjacent organs, will alike mechanically produce jaundice, though their other symptoms differ widely. Again, it is often a symptom of inflammation of the liver, as especially in yellow fever, and of inflammation of the duodenum. But the most frequent cases are those which do not appear to be the consequence of any organic disease, but are accompanied by the symptoms of general disorder of the digestive organs, as nausea or vomiting, thirst, and loss of appetite, confined or irregular condition of the bowels, headache, and general uneasiness. These cases generally come on suddenly, as a sequel of common diarrhœa, or in the dyspeptic and those of a sedentary habit, or whose bowels have been long inactive. It is often difficult to say what prevents the excretion of the bile; sometimes it is separated from the blood in too viscid a form; sometimes mucus appears to obstruct the duct; in many cases there is probably spasm of the duct, as in those which occur after violent fits of anger or other mental affection; and in some a larger quantity of bile appears to be formed than can be conveyed away with proportionate rapidity.

It is impossible that any one mode of treatment should be adopted for a symptom depending on such varied causes. Where the obstruction is mechanical, the jaundice is of course curable only by the removal of its evident cause; and in inflammation of the liver it is but a symptom of a more important disease, to which the treatment must be directed. In the more common cases, which, as distinguished from these, are sometimes called functional, the treatment should consist chiefly of small doses of mercury, and active purgatives containing the neutral salts. Warm baths and opium should be used, if there be any spasmodic pain of the right side; and leeches, if any inflammatory pain or tenderness be felt. A mild diet and the avoidance of all stimulant drinks or food should be carefully enjoined.

JERVINE ($C_{60}H_{45}N_2O_5 + 4$ aq.). *Jervina*, a vegetable alkaloid found with veratrine, colchicine, and sabadilline in white hellebore root. It is white and crystalline, and melts when heated into an oleaginous liquid; at a higher temperature it takes fire, and burns with a sooty flame, without any residue. It is nearly insoluble in water, but dissolves in alcohol.

Its compounds with hydrochloric, sulphuric, and nitric acids, are but slightly soluble in water and acids; the acetate dissolves readily in water; ammonia decomposes the solution and occasions a bulky precipitate of jervine.

JESUITS; SOCI'ETAS JESU. [LOYOLA, in BIOG. DIV.]

JETSAM. [FLOTSAM.]

JEWELLERY; JEWELLING. It may be desirable to explain briefly the sense in which the words *jewellery* and *jewelling* are understood, as manufacturing terms.

Jewellery.—A jewel is a gem or precious stone, such as the diamond, sapphire, ruby, &c. The cutting of these gems, to give them a particular contour as well as reflecting facets, is the art of the lapidary, who works with very small sharp-edged wheels; the wheels are made to rotate rapidly; and their edges are touched with the powder of some substance harder than that which is to be worked upon; the gem is thus ground away rather than cut—although it is sometimes severed into portions by a process midway between cutting and slitting. The different gems themselves are described under their proper names, as objects of mineralogy, in the NATURAL HISTORY DIVISION of this Cyclopædia; the mode of cutting will be sufficiently understood by reference to many of those articles, to CAMEO and EMERY, and to the latter portion of the present article; while the process of making artificial or factitious gems occupies one of the sections in GLASS MANUFACTURE.

The word *jewellery*, however, has a wider sense than this. It comprises the *setting* of precious stones, and also the manufacture of small ornamental works in gold and silver, even when no precious stones are employed in them. The line of distinction between a goldsmith and a jeweller is not very marked, so far as the original meaning of the word is concerned; but there is a certain well-understood trade distinction. Goldsmith's work, under the general name of *plate*, comprises the articles which are stamped at Goldsmith's Hall and similar places; while *jewellery* comprises the smaller articles which are not so stamped.

There are great differences in the quality of the gold employed. Absolutely pure gold being technically called "24 carats fine," all other gold is named according to the ratio between fine gold and the alloy, estimated in 24ths. The alloy may be silver, or copper, or a mixture of both. Old *standard* gold used to have, and *sterling* gold still has, 22 of gold to 2 of alloy; new standard has 18 to 6. None below this can receive the "hall mark," or Goldsmith's Hall stamp. Gold of lower quality is often known by its value per ounce, as 60*s.*-gold, 40*s.*-gold, &c. Gold as high as 22 carats can rarely be used in jewellery; it is too soft. The so-called *fine*-gold of the jewellers is now usually about 16 carats; if meant to imply that the gold is pure, the word is of course, a deception. The announcement in shop-windows, "Fine gold chains, weighing 5 sovereigns each, for *5l.*," is little less than a fraud. Indeed, as ordinary purchasers have no means of testing the quality, there is scarcely any limit to the debasement of the metal employed. Plate *must* not be below a certain standard; jewellery *may* be, and *is*—in other words, *pure*, *sterling*, and *standard* gold have definite meanings; whereas, *fine* and *jewellers'* gold have not. It will thus be understood how gold chains, and such like articles, vary so much in value without varying much in appearance. By using a little more silver in the alloy, the tint is heightened; by using a little more copper, it is deepened; and thus the tint of pure, or nearly pure, gold can be very nearly imitated. A troy ounce of absolutely pure gold is worth *4l. 4s. 11½d.*; of *sterling* gold (22 carats), *3l. 17s. 10½.d*; of new *standard* gold (18 carats), *3l. 3s. 8½d.*; of 12-carat gold, *2l. 2s. 5½d.*; of 8-carat gold, *1l. 8s. 3½d.*—and so on; therefore, the value of an ounce of so-called gold is wholly indefinite, unless the ratio of alloy be stated. Some jewellers' gold is as low as 3 carats, not worth more than about 9*s.* per oz. The makers of cheap chains, pencil-cases, lockets, &c., have discovered that if zinc be used instead of silver as an alloy, the appearance is improved; and thus the intrinsic value of the gold is brought lower than ever.

There are many compositions and many imitations of gold, used by artificers. A *liquid* gold is formed from a solution of terchloride of gold agitated with ether; it is used for producing devices on steel, &c., by leaving a coating of pure gold when dry. *Gold bronze*, or *gilding powder*, is often made on a small scale by grinding up gold-leaf with honey. *Dutch gold*, also called pinchbeck and tombac, is made in Holland and Prussia, by combining 11 parts of copper and 2 of zinc, and rolling the compound into thin sheets. *Grain gold* consists of nearly pure gold, employed in making various preparations. A *factitious* gold, consisting of copper 16, platinum 7, and zinc 1, presents nearly the colour and appearance of gold of 16 carats. *Mosaic gold* is made from bi-sulphuret of tin, or from various brassy compounds of metals. Messrs. Mourier and Vallent, in 1857, introduced an *artificial* gold for ornamental work, which is said to be fine-grained, malleable, fusible for casting in a mould at a low heat, and susceptible of a good polish. It consists of copper 100, tin 17, manganese 6, sal-ammoniac 4, quicklime 2, and tartar 9.

The processes of jewellery, as a branch of goldsmith's work, need no description; they comprise small or fine examples of casting in moulds, stamping with dies, wire-drawing, hammering and filing, burnishing and lacquering, &c.

Jewelling.—Jewelling, unlike jewellery, is a term wholly applied to gems, and not likewise to working in gold. It is especially applied to the jewelling of watches. This consists in setting diamonds, rubies, sapphires, chrysolites, or other hard stones, in the frame-plates and other parts of watches, in such a manner that the pivots of the watch may act in holes made in these stones. There are two kinds of jewelled holes necessary in watches, one of which is merely a perforation through the stone; the other consists of a perforated piece, and a piece called an end-piece. The province of the watch-jeweller is to select the stones, and, except in the case of diamonds, to grind, polish, turn, drill, and set them into the frames or other parts of the watch in such a manner that the holes in the stones may correspond exactly in position with holes previously made by the watch-finisher or escapement-maker. A hole *without* an end-piece is thus made. The hole in any piece to be jewelled having been made in its proper place by the finisher, the piece is so fixed in a lathe by the jeweller that the hole shall be perfectly concentric with the centre of motion; this hole is then enlarged by turning, and afterwards so formed that a small circle of brass which contains the stone, and which is called the setting, may have a cavity to rest in, without the possibility of its going through the plate or piece in which the hole has been made. After the setting has been fitted to the cavity, and adjusted so as to be flush with the plate, two screws are inserted in the plate so near to the cavity which contains the setting that the edges of the screw-heads project a small distance over the edge of the setting, and thereby secure it in its place. When a hole *with* an end-piece is required, the same process is adopted, but two stones are required for each hole instead of one; and the first, or perforated stone with its setting is sunk into the cavity a sufficient distance below the surface of the plate to allow of the reception of a second setting, containing a stone which resembles in form a small slice cut from a sphere about the size of a shot, its form being plano-convex. The edge of this second setting is left flush with the plate or piece in which the cavity is made; and two screws being inserted, as in the former case, the two settings are secured at once. In the holes already described the stones are secured in their brass settings in a manner somewhat similar to that in which opticians set many of their glasses in telescopes: namely, by turning a place to receive the stone, and leaving a fine edge of brass, which is subsequently rubbed over the edge of the stone with a burnisher. When a diamond end-piece is used, it is usually set in steel, into which it is brazed, the diamond being a stone which will allow of heat sufficient for that purpose. After brazing, the steel is turned into shape, polished, and blued.

The apparatus necessary for the jeweller to carry on his business consists of a small lathe; small gravers for turning brass and steel; a quantity of rough diamond in fragments, technically termed *bort*; small mills or circular discs of metal (usually copper) for grinding the stones into shape; diamond powder of various degrees of fineness for polishing; and turning tools made by cementing small pieces of bort into a notch made in the end of small brass wires and fixed in proper handles. In the preparation of a stone for a jewel-hole, it is necessary first to charge a copper disc about the size of a penny piece, and out of which it is frequently made, with bort; the mill thus prepared is fixed unto the mandrel of the lathe, which is put in motion by a band from a rather large foot-wheel, the mill making from 6000 or 7000 to more than 20,000 revolutions in a minute, the latter velocity being given only in the act of polishing. The stone to be formed is then taken on the end of one of the fingers of the right hand and applied to the surface of the bort mill, which is kept constantly wet with water applied by the fingers of the left hand, and in a few seconds a flat surface is produced on a stone of the most irregular form; the flat surface is then placed next the finger, and a similar surface is produced parallel to the former, until the stone is of such a thickness as is required. The stone is then placed, by means of cement, on a small chuck in the lathe; and with one of the before-mentioned bort tools is turned into the proper shape for setting. The hole is also drilled either with a steel drill and diamond-powder and oil, or with a drill made of bort or small fragments of diamond. The piece of stone, or hole, as it is called, is also turned with a hollow, or countersink, to receive the oil necessary for the lubrication of the pivot. The stone is afterwards detached from the lathe, and its flat or parallel surfaces polished by rubbing it on a piece of plate-glass, previously charged with a small quantity of diamond-powder and oil. When an end-piece is required the same process is gone through, except that the drilling is omitted, and the spherical side of the stone is polished by using a piece of brass with a hollow end to suit the convexity of the stone. The jeweller also makes use of a small spirit-lamp to heat the cement when he applies it for the purpose of securing the stones upon the chucks in the lathe. The end-pieces, when real diamonds are used, are what are called rose diamonds, and are procured from Holland, where they are cut.

It may here be added that small jewels, such as bits of ruby, are sometimes used for the nibs of pens; and that diamonds, rubies, and garnets, are made into exquisitely minute lenses for microscopes.

JEW'S-HARP, a musical instrument of the simplest and rudest kind, consisting of an iron frame, resembling in form the handle part of an old-fashioned corkscrew, in the centre of the upper and wide part of which is riveted at one end an elastic steel tongue, the extremity of which, at the free end, is bent outwards to a right angle, so as to allow the finger easily to strike it when the instrument is placed to the mouth and firmly supported by the pressure of the parallel extremities of the frame against the teeth.

Mr. Wheatstone has shown that the sounds of the Jew's-harp mainly depend on the reciprocation of columns of air in the mouth of the performer, and that these sounds are perfectly identical with the multiples of the original vibrations of the instrument. Hence its scale must necessarily be very incomplete; but by employing two or more instruments the deficiencies are supplied. Some years ago, an ingenious foreigner, M. Eulenstein, exhibited in London, at the Royal Institution, and afterwards at various concerts, his very extraordinary talent on the Jew's-harp. He used sixteen instruments of different sizes, and was thus enabled to modulate into every key, and to produce effects not only original, but musical and agreeable.

JEWS (Ἰουδαῖοι and *Judæi* in Greek and Latin, *Jehudim* in Hebrew), in its widest acceptation, is used as synonymous with Hebrews, or Israelites, but in a more restricted sense it means the inhabitants of the kingdom of Judæa as it existed in the time of Jesus Christ, and whose descendants are now scattered over all the world. The history of this people previous to the time of Christ is contained in the Old Testament and in Josephus, and need not be repeated here. The resistance made by the Jews to the power of Rome resulted, first, in the dominion of the Asmonean princes, of whom an account will be found under ASMONEANS, in the BIOG. DIV.; and, later, in their having been forced by tyranny into rebellion, in the destruction of the Temple by Titus. The Jews then became a dispersed people; and, therefore, from about the time of the birth of Our Saviour we give a slight sketch of their history. It has to be observed, however, that the character of the Jews had undergone a considerable change during their Babylonish captivity. They had become more exclusively attached to their country and their laws, and we hear no more of their proneness to idolatry after that epoch, as in former times. They strictly avoided intermarriage with foreigners, and assumed in every respect that unsocial spirit towards all except their own community for which they have been so often reproached. Adversity had soured their minds, while the expectations of a Messiah who was announced by their prophets roused the national pride. The doctrine of the immortality of the soul, which is not mentioned in the Mosaic law, was also introduced, especially among the great sect of the Chasadim, or Pharisees.

The last of the Asmonæan dynasty was put to death by Herod, son of Antipater the Idumæan, who, with the support of the Romans, became king of Judæa B.C. 38. [HEROD THE GREAT, in BIOG. DIV.] He died in the same year that Christ was born, although in the common chronology the birth of Christ is placed four years later. With Herod the independence of Judæa may be said to have expired. His son Archelaus was appointed ethnarch of Judæa Proper, Idumæa, and Samaria; his brother Herod Antipas had Galilee and Peræa; to Herod Philip were given the provinces of Trachonitis, Batanæa, and Gaulonitis, east of the Jordan; and another Philip had Ituræa. Thus the dominions of Herod were dismembered between four of his sons, who are accordingly styled Tetrarchs in the New Testament. Archelaus was summoned to Rome after a reign of nine years, to answer certain charges brought against him by his subjects, and was banished by Augustus to Vienne in Gaul. Judæa thus became a Roman province, or rather a district dependent on the great province or prefecture of Syria, though administered by a special governor, a man usually of the Equestrian order. This is the state to which Judæa was reduced in the time of Our Saviour. The Jews, however, continued to enjoy the exercise of their religious and municipal liberties.

Under the reign of Claudius, Herod Agrippa, grandson of Herod the Great, who had been already appointed by Caligula ethnarch of Galilee, was appointed king of Judæa and all the former dominions of his grandfather; but he died three years after, at Cæsarea in Palestine, A.D. 44. This is the Herod mentioned in chapter xii. of the Acts. His son, called likewise Herod Agrippa, was then a minor, and Judæa relapsed into a Roman province. In A.D. 53 Claudius gave to Agrippa the provinces east of Jordan, which had belonged to Philip the Tetrarch, and Nero added to them part of Galilee. But Judæa and Samaria continued to be administered by Roman procurators. Herod, however, was entrusted by the emperor with the superintendence of the Temple and the right of appointing and deposing the high-priest at Jerusalem, and he occasionally resided in that city, while the Roman governor generally resided at Cæsarea. This second Herod Agrippa is the one mentioned in Acts, xxv., xxvi., there styled King Agrippa, whom St. Paul addressed in so impressive a manner in his defence. Agrippa was present at the final catastrophe of Jerusalem.

A succession of more than usually rapacious Roman governors—Felix, Albinus, and Florus—had driven the Jews to the verge of despair. A revolt took place, beginning at Cæsarea, which was only terminated by the taking of Jerusalem in A.D. 70. Still the Jewish population was by no means extirpated from the country, and we find them rising in vast numbers in the reign of Hadrian, and again engaging the Roman legions commanded by Severus. They were however overpowered with immense slaughter, and the second desolation of Judæa took place.

The dispersion of the Jews over the world, which is commonly dated from the destruction of Jerusalem, had in reality begun long before. The Ptolemies had transplanted large colonies of them into Egypt, Cyrene, and Cyprus; and Antiochus the Great settled great numbers in the towns of Asia. In the time of Cicero (' Pro Flacco ') there was a wealthy Jewish community in Italy. A passage of Philo, in his letter of Agrippa, enumerates the countries in which the Jews were settled in the time of Caligula: Egypt, Syria, Pamphylia, Cilicia, the greatest part of Asia Minor as far as Bithynia, the shores of the Euxine, Macedonia, Thessaly, Ætolia, Attica, the Peloponnesus, Cyprus, and Crete, besides the countries beyond the Euphrates; for at the end of the Babylonish captivity many Jews voluntarily remained in Mesopotamia, where they continued to form for several centuries a considerable community, alternately under the Parthian and Roman dominion.

Ascribing their continued misfortunes to the non-observance of the Mosaical laws, the Jews now established schools for the stricter inculcation and study of them; and that of Tiberias was particularly celebrated. From these schools issued the Mishna and the Gemara; the first by Rabbi Jehuda, the second by Rabbi Ascha and his disciples; the whole forming the Babylonian Talmud. Many learned Rabbis distinguished themselves as opponents of the constantly increasing Christian faith. When the Eastern Empire had adopted Christianity, the Jews, who had hitherto lived undisturbed, were placed under many restrictions. They were forbidden by Constantine to receive Christian converts, or to possess Christian slaves. Under Constantius, his successor, a tumult in Alexandria, in which they were implicated, led to fresh enactments against them, and to additional taxation; and subsequently Tiberias was burnt, and the school destroyed. Under Julian they were favoured, and he proposed to restore the temple, a project never completed. His successors renewed the severities against them, and in A.D. 415, after a tumult, 100,000 Jews were expelled from Alexandria.

Theodoric and the other Gothic kings of Italy protected the Jews. During the frequent wars and invasions of that period, the Jews had the slave-trade of Europe in a great measure in their hands; and Pope Gregory I. and several councils interfered to prevent their abusing the power which they had thus acquired over the persons of Christians. That wise and humane pope, in his pastoral letters, bewails and denounces this traffic, which was carried on in Italy, Sicily, Sardinia, and France; he directs the bishops to interfere so as to prevent Jews from retaining Christian slaves when a proper price was offered for them. On another occasion he directs that those Christian slaves who had been long in possession of Jewish landed proprietors should be considered as villains attached to the soil, and should not be transplanted or sold away; he also entreated the Frankish kings to banish the traffic in slaves from their dominions.

Justinian was one of the first who enacted really oppressive and intolerant laws against the Jews. One of these laws declared that all unbelievers, heathens, Jews, and Samaritans could neither be judges, nor prefects, nor fill any other dignity in the state; and another enacted that in mixed marriages between Jews and Christians the chief authority over the children should rest with the Christian parent. The Longobards in Italy maintained the severities that Justinian had imposed upon the Jews; and by the West Goths in Spain they were forbidden to hold their sabbath or celebrate their Passover according to the Mosaical law.

The Jews however were too numerous and strong to be annihilated by imperial edicts: they had even the power of revenge. When Chosroes II. invaded Syria, the Jews of Palestine rose to join the Persians, with whom they entered Jerusalem, then a Christian city, and perpetrated a dreadful slaughter of the Christian inhabitants. They are said to have purchased at a cheap price the captives of their allies the Persians, for the sake of murdering them. The victories of Heraclius however put an end to their momentary triumph.

The rise of Mohammedanism brought an unfavourable change to the Eastern Jews. For a short period a Jewish dynasty was seated on the throne of Yemen in Arabia, but it was dispossessed by a king of Ethiopia, about the beginning of the 6th century. Jews however still continued numerous in Arabia; Mohammed endeavoured at first to win them over, but though at first they gave him some support against the pagans, they would not acknowledge a descendant of Hagar the bondwoman as the greatest of prophets, and Mohammed treated them without mercy. Under the Caliphs his successors they were protected on the easy terms of paying tribute, and as they made no resistance, they experienced not only protection but even encouragement from their new masters, whom they followed through their tide of conquest along the coast of Northern Africa. They also contributed materially to the triumph of the Crescent in the Spanish Peninsula. About the middle of the 8th century, a sect of Jews separated themselves from the main body, who were called Karastes. Their founder was Anan, who lived in Babylonia. This sect, which disclaimed the traditions of the Rabbis, and rejected the Talmud, spread itself widely through Palestine, Egypt, Syria, and Arabia, and for many years had an acknowledged chief, who dwelt at Cairo.

The intolerance the Jews had experienced in the Spanish Peninsula from the Gothic kings had driven large numbers to the opposite shores of Africa, whence many returned with the Saracen invaders; and the munificence of the Mohammedan princes towards them indicates that by their knowledge of the country the Jews had been highly instrumental in advancing the conquest. In Moorish Spain the Jews had really a golden age, which lasted for centuries. There they cultivated science and learning; and the names of Benjamin of Tudela, Isaac of Cordova, Hasdai, the confidant of Abderrahman, and a host of others, attest their proficiency. Rodriguez de Castro (' Bibliotheca Española ') and Vicente Ximeno (' Escritores del Reyno de Valencia ') give notices of the writings of the Spanish Jews. At the same time they were thriving in the East under the caliphs of Bagdad, whose favour they enjoyed, at least till towards the end of the 10th century; and in Egypt, where they were protected by the Sultan Saladin, who employed the celebrated Maimonides as his physician.

Although at first partially employed by the Christian princes of Spain on account of their financial and scientific abilities, the position of the Jews became gradually more irksome as the Moorish power declined. In 1391 an archbishop of Sevilla excited the populace against them, and it is stated that of 7000 families, one half were slain, while 200,000 were enumerated as real or pretended converts to Christianity. Even these were not left in peace. The regular Inquisition established under Ferdinand and Isabella undertook the task of punishing all relapsed converts. As for the unconverted Jews, the edict of 1492, made at the instigation of the Inquisitor Torquemada, banished them all from the kingdom. The number of Jews thus expelled from Spain has been vaguely estimated at half a million, and even 800,000. They were allowed to carry away or sell only their moveables. Few of them consented to embrace Christianity in order to remain. Soon afterwards they were driven away from Portugal also with circumstances of still greater barbarity. Many perished, and others took refuge on the African coast. The expulsion of the Jews and that of the Moors or Moriscoes drained Spain of its most useful subjects. It was not till 1837 that even a slight amount of toleration was granted to them; but the numbers in the Peninsula even now are so few that they are not given in the general estimate of the total number of Jews; which for Europe may be about 3,500,000, as the ' Almanach de Gotha ' for 1860, gives details amounting to 3,136,499, and does not include Great Britain, Bavaria, Belgium, Electoral Hesse, or Wurtemberg.

Charlemagne protected the Jews like his other subjects: they filled municipal offices; they were physicians and bankers; and Isaac, a Jew, was chosen by that emperor as his ambassador to Haroun al Rashid, caliph of Bagdad, a mission which was considered of the greatest importance at the time. The Jews enjoyed the same or even greater influence under Louis le Debonnaire and Charles the Bald, but towards the end of the latter reign the clergy began afresh to show their hostility. The Council of Meaux re-enacted the exclusion of the Jews from all civil offices; but it was under the third or Capet dynasty that the Jews suffered actual persecution in France. Philippe Auguste, pressed by the wants of an empty exchequer, and perhaps also by the reports of fanatics, who charged the Jews with all sorts of crimes, banished, in 1180, all the Jews from his dominions, confiscated their property, and declared all debts due to them to be annulled. About twenty years afterwards the Jews were allowed to re-enter France, which they did in great numbers. This was the beginning of a series of alternate proscriptions and relaxations, continued under the following reigns for about two centuries, until they were expelled under Charles VI. in 1394. Although the laws continued very severe against the Jews, and were sometimes invoked with much zeal, many continued to reside in France. The Revolution of 1789 brought them relief; all Frenchmen were declared equal; and throughout the political and constitutional changes which have since taken place in France, their rights have been respected. Napoleon I. in 1806 assembled a sanhedrim at Paris, and submitted to them twelve questions concerning the moral and social doctrines and discipline of the Jews. Their answers being found satisfactory, an ordinance was issued giving the Jews a regular organisation throughout France. They are subjected to the conscription, and are assessed to taxes like the rest of their countrymen; and they are eligible to all political employments, in which some of them have reached the highest ranks. The Jews in France, in 1856, numbered 73,995.

In Germany perhaps the Jews have suffered the most persecution, although they have always been numerous there, especially in the free towns. Besides the severities of the laws, they were exposed to sudden bursts of popular fanaticism. They were massacred at the cry of "Hep," "Hep," the initials of the word "Hierosolyma est perdita." St. Bernard and Pope Eugenius III. loudly reprobated these atrocities. These persecutions almost of necessity drove them to the practice of usury, as affording the best security against their effects being plundered by a mob. In 1782 the writings of Lessing, Mendelssohn, and others began to produce their effects, for in this year an Austrian edict for a limited toleration was issued; by 1803 the capitation tax was removed from them in all the states of the German empire; by 1811 the rights of citizenship had been extended to them in most of the smaller German states; in 1812 they were placed nearly on an equality with their fellow subjects in Prussia; by 1833 this had extended to all the other states; in the disturbances of 1848 they were promised an entire equality, but the promise has not been as yet fulfilled. The Jewish population in Germany is large; in the Prussian territories, in 1855, they numbered 234,248; in the Austrian empire they amounted to 853,304. Among the smaller states, ducal Hesse has the largest proportion, there being 28,700 Jews in a population of 845,571.

In Italy the Jews seem to have enjoyed greater though not always uninterrupted security. They were expelled from Naples and Sicily by Charles V., although he afforded them a moderate amount of protection in the empire. But in the Italian republics and trading towns the Jews formed a numerous and prosperous body, from their commercial aptitude, and more particularly from their trading intercourse with the Levant. In the Papal territories they were sometimes tolerated and sometimes persecuted; but here, as elsewhere, the Reformation has worked in their favour. They were, however, confined to a particular quarter in the towns, called the ghetto. Sardinia permitted them to become possessors of landed property, and this privilege, with others, will now be extended to a wider circle. In Italy there are supposed to be 47,000 Jews.

In Holland, Denmark, and Sweden, more especially since the Reformation, the Jews have lived undisturbed; and in Holland they have long formed a highly flourishing, numerous, honourable, and intelligent community, amounting in 1859 to 64,070 in number.

In Poland, Casimir the Great, about 1360, afforded an asylum to the Jews when they were being persecuted in almost every other part of Europe. They became numerous, and diffused themselves widely into Russia. Their united numbers in those states in 1858 is given as 1,821,678; and though not in all respects on an equality with the citizen, they enjoy many privileges, and are generally above the serf. They are seldom cultivators, and in many districts have almost entire possession of some peculiar profession or trade.

Throughout the dominions of the Sultan the Jews are allowed to settle and follow their trades, though looked upon with scorn by the Osmanlees; and they number, it is stated, 300,000. In the regencies of Barbary they have settled likewise in great numbers.

(Jost, 'Allgemeine Geschichte des Israelitischen Volkes;' Millman, 'History of the Jews;' Ersch and Gruber's 'Allgemeine Encyklopädie;' Meyer's 'Grosse Conversations-Lexicon;' 'Almanach de Gotha,' 1860.

It does not appear at what time the Jews found their way to this island, but they were settled here in the Saxon period, and as early as A.D. 750. From the time of the Conquest the Jews in England rapidly increased in number. Under the first three Norman kings they lived undisturbed, so far as we are informed, and apparently acquired great wealth. But under Stephen and his successors they suffered grievously from the rapacity of the kings and the bigoted intolerance of the people. The cruel persecutions which they experienced from all persons, both lay and ecclesiastic, poor and rich, are fully attested, not by their own writers, but the evidence of their enemies. Finally, in the reign of Edward I., about 1290, all the Jews were banished from the kingdom. Their numbers at that time are conjectured (but on what grounds we are not aware) to have been between 15,000 and 16,000. It was not till after the Restoration, 1660, that the Jews again settled in England; and though under the Protectorate they had entered into negociations with Cromwell to obtain permission to enter the island, nothing seems to have been done in the matter, and those who have investigated the subject bring forward no proof of leave being formally granted to them to return. After the Restoration it seems probable that they came in gradually without either permission or opposition, and since that time foreign Jews have been on the same footing as other aliens with respect to entering the country. In the year 1753 an act was passed to enable foreign Jews to be naturalised without taking the sacrament; but the act was repealed in the following session, under the influence of the popular feeling, which was most strongly opposed to the measures of 1753. Since that year they have lived in the United Kingdom unmolested.

During their residence in England, up to their banishment in the time of Edward I., the Jews were considered as the villains and bondsmen of the king, a relation which seems to explain the power over their persons and property which was assumed and exercised by the king in the most oppressive manner. They however could purchase and hold land, subject only to the right of the king, whatever it might be, to levy heavy taxes on them and seize their lands if they were not paid. By the act of the 55th of Henry III. the Jews were declared incapable of purchasing or taking a freehold interest in land, but might hold, as in time past they were accustomed to hold, houses in the cities, boroughs, and towns where they resided. Another act, 3 Edward I., forbade Jews from alienating in fee, either to Jew or Christian, any houses, rents, or tenements which they then had, or disposing of them in any way without the king's consent; they were permitted to purchase houses and curtilages in the cities and boroughs where they then resided, provided they held them in chief of the king; and they were further permitted to take lands to farm for any term not exceeding ten years; such permission however was not to continue in force for more than fifteen years from the date of the act. Since the time of their banishment no statute has been passed which in direct terms affects the right of the Jews to hold real estates in England; and it has been a matter of dispute whether they could legally hold such estate.

In March, 1828, the first step was taken towards their emancipation by the Corporation of London rescinding their order of 1785, that baptised Jews should not be admitted to the freedom of the city. From 1831 repeated Bills were brought into the House of Commons for the removal of the political disabilities of the Jews, which in 1836 and 1842 were passed in the lower house but rejected by the Lords. In August, 1846, however, an act was passed (9 & 10 Vict. cap. 59,—Religious Disabilities Relief Act), by which they were enabled to hold landed property, to endow schools and other charitable foundations, and repealed the provisions as to their dress, the necessity of attending Christian worship, and as to their wearing a badge of yellow taffeta. The next year another act legalised their marriages. In 1855 their places of religious worship were placed on the same footing as those of Roman Catholics and Protestant Dissenters. By the Reform Act in 1832 they had been admitted to the exercise of the elective franchise; and by the 21 & 22 Vict. cap. 49, passed July 23, 1858, they were made eligible for seats in Parliament, by the omission from the usual oath "on the true faith of a Christian," in any case where the person elected shall declare himself to be a Jew.

The number of Jews in the United Kingdom has been estimated at 30,000, which is probably under the real number. Of these, 20,000 are supposed to be in London; while in Scotland and Ireland their numbers are few. According to the Census of 1851, the Jews in England and Wales had 53 synagogues, with accommodation for 8438 worshippers; in Scotland only one synagogue, accommodating 67 worshippers, at Edinburgh. They are also numerous in the British colonies and in the United States of America. They are to be found in every quarter of the known world, even in China; and in Morocco and other parts of Africa, as well as in Asia, they are comparatively numerous; while in very few places is there now any active persecution against them or their faith.

JIG, or GIGUE, an animated quick dance-tune, in six-eight time, to be found in the sonatas of Corelli, Handel, and other composers till towards the middle of the 18th century. The *jig*, or at least the name, is unknown in modern music; though in a French work of recent date, we are told that it is still in use in England.

END OF VOLUME IV.

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